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A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries

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EDITORIALS

RESEARCH AS AN INVESTMENT

One notable result of the European War has been the marked change in the status of industrial research in this country. Before the war research was looked upon as an interesting side-issue of academic life, very indirectly related to factory management, but from the financial standpoint to be considered a non-essential luxury. During the war, the value and necessity of research were well proven, and consequently it has received a tremendous amount of advertising. To-day industrial research is not only respected; it has reached the enviable, but precarious, position of being a fashionable investment. Almost every day we hear of some trade organization or large industrial corporation that is anxious to invest a considerable sum in research. The money is available; the question is how shall it be invested wisely? This question is of considerable importance both to the investors and to all who are interested in the development of research. A few unwise and unprofitable investments at this time will give a decided set-back to the growth of industrial research in this country.

Conservative investment in research, like investment in land or stocks and bonds, must be a matter of detail. It is necessary to invest in definite researches. Many firms and associations which are attempting to invest in research generally, by establishing laboratories and hiring staffs of investigators, without having a definite research program, will be simply lucky if their investments prove profitable. Their chances for financial returns lie in the facts that the field for research is so broad, the

possible applications of results obtained are so varied, and the financial returns from even one successful application are so great that even ill advised and poorly directed researches, amply financed and persistently conducted, may yield large profits. The undertaking of research on such a plan by an organization with limited financial resources must be considered as speculation. When undertaken as a long-time project by an organization with abundant resources and with staying power it becomes investment.

The first step in conservative investment in industrial research is to make a survey of the field and to decide just what researches shall be undertaken. Of course, experts should be asked to make this survey; and these should be of two types, the engineering and the scientific. Engineers, thoroughly experienced in the particular industry in question, can tell just what is known about the subject and the possibility of improvement by the efficient application of this knowledge or moderate extension of it. It is surprising how often researches are conducted for the purpose of improving methods of manufacture when what is really needed is better engineering and factory management. On the other hand, it is the special function of scientists to tell of the possibilities of development by researches based on theoretical considerations.

For conducting researches two general methods are available, the empiric, or engineering, and the theoretical, or scientific. The empiric method is ordinarily used by engineers in conducting investigations. As is well known it consists in starting without any theory and by empiric trials collecting data for use in deriving an engineering formula or the basis of a new process of manufacture. In the scientific method, the investigator starts with a theory and conducts investigations to see whether the theory is applicable. Of course, engineers sometimes use the scientific method and scientists the theoretical one; but the use of the empiric method by engineers and the theoretical method by scientists is rather characteristic. In some quarters there is a tendency to decry the use of the empiric method in research, but it has been and will remain an important factor in the development of all industries. Most of the researches reported in the publications of this Society are of the empiric type.

Empiric researches usually keep close to established engineering practice and are rather more certain to yield usable results than theoretical researches. On the other hand, these results are not as spectacular and revolutionary in their effects as the results of the occasional successful research based on theory. As investments empiric researches may be considered as safe; but, like all safe investments, they yield a comparatively moderate return on the money invested. Researches based on theory must be considered more hazardous investments, but they yield large returns if successful.

As to the men to be chosen for actually conducting researches, we may say that there is no such thing as an ideal research man. An efficient research staff must consist of at least two men, an engineer and a scientist—the engineer to get the work done, and the scientist to perceive and make use of the by-products of the investigation. The engineer is primarily a man of action. He sets himself a goal and works directly toward it; he gets the job done. Because of this directness of aim and concentration of effort he is very liable to overlook or neglect interesting and often potentially valuable facts that may come to light during the research. On the other hand, the typical scientist is a man of imagination and omnivorous curiosity. He is interested not only in arriving at a fixed goal but also in exploring all the by-paths leading off from the direct road. He loves not only to note directly useful data but also to allow his imagination to play with the possible utility and meaning of seemingly adventitious phenomena. Moreover, unlike the engineer, the scientist is not satisfied with finding one efficient way of doing a thing, but is interested in investigating all the refinements of the various possible ways. For these reasons scientists are slow in completing set tasks.

Therefore, in industrial research men of the engineering type should be employed for executing specific researches and scientists for assisting in planning investigations and for conserving the by-products of researches.

ORIGINAL PAPERS AND DISCUSSIONS

PRODUCER GAS AS FUEL FOR THE GLASS INDUSTRY

By F. J. Denk

The continuous decrease in the supply of natural gas, on the one hand, and the steady increase in the cost of coal on the other, has forced glass manufacturers to look for either a cheaper fuel or for a means to burn their present fuel in a more economical and more satisfactory way than before. The fuels at hand at the present time are natural gas, coal or coke and oil. The amount of natural gas available for the industries is declining rapidly. The cold spells we had this winter forced many a factory, which had to rely exclusively on natural gas as fuel, to shut down completely. The present price of coal is too high to allow coal to be wasted; but this is done as long as coal is burned in a direct-fired furnace, either using the coal as such, or having a gas producer built integral with or close to the furnace and using the producer gas without any regeneration. The same holds good for coke used directly in lehrs, glory-holes, and so forth. Oil, finally, is a very expensive fuel, at least in western Pennsylvania and eastern Ohio. In and around Pittsburgh, for instance the price of fuel oil was, before Christmas, $11^3/_4$ cents per gallon. This price corresponds (see figure 1) to about $17.50 per ton of coal, figuring straight conversion with a 12,500 B. T. U. coal and 80 per cent furnace efficiency. Counting on about $1.00 for fixed and overhead charges per ton, which is fairly high, still leaves a coal price of $16.50 per ton. Since we can get, in many cases, coal for between $3.00 and $4.00 per ton delivered at the factory, it can easily be seen that a price of $11^3/_4$ cents per gallon of oil is prohibitive.

In the districts along the coast, where oil is comparatively cheap, conditions are somewhat different. But even there coal, costing, say, $5.00 per ton, will give producer gas which can compete with oil at 4 cents per gallon. It is true, the first cost of an oil installation is cheaper than that for a producer gas installation. But this advantage is more than offset by the high operating cost. To illustrate this, I have calculated the first cost and the operating cost for an oil plant and for a gas producer plant, the latter for hand-poked producers and for mechanical

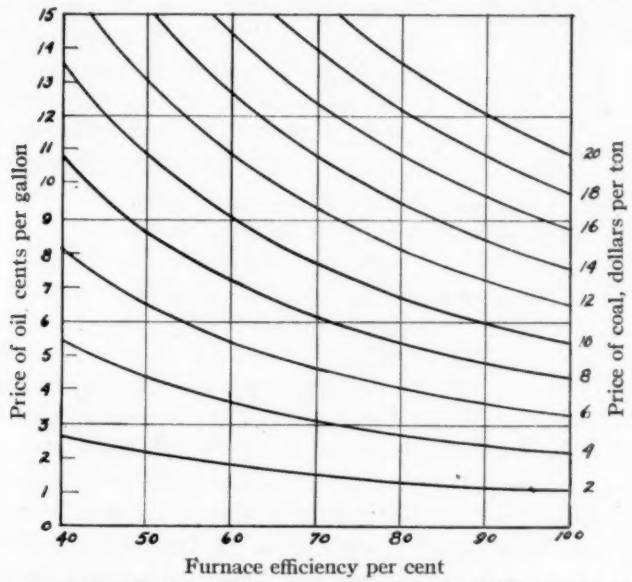


FIG. 1.—Equivalent price of oil in cents per gallon for different coal prices in dollars per ton and different furnace efficiencies.
Direct conversion; coal with 12,500 B. T. U. per pound.

producers. Basing the calculation on a daily consumption of 1,500,000 cu. ft. of natural gas, we get (see Appendix and the accompanying table) when figuring on $11^3/_4$ cents per gallon of oil and $3.50 per ton of coal:

First cost of an oil plant	$36,500
First cost for a gas producer plant	
with hand-poked producers	$46,500
and with mechanical producers	$65,500

The corresponding operating cost per day is then:

$1409.40 for oil,
$ 355.28 for hand-poked producers, and
$ 340.11 for mechanical producers.

This shows, that, although the first cost of a gas producer plant with mechanical producers is about 80 per cent higher than the first cost of an oil plant, the operating expenses for such a plant are only about 24 per cent of the operating expenses of an oil plant. The equivalent cost of natural gas for the three installations in question is: 94 cents per 1000 cu. ft., 23.7 cents per 1000 cu. ft. and 22.7 cents per 1000 cu ft., respectively. Oil, therefore, can compete in our case with artificial gas only, selling at $1.00 per 1000 cu. ft.

Based on a daily consumption of 500,000 cu. ft. of natural gas, the first cost as well as the operating cost for the three installations will be smaller, but the equivalent cost of natural gas is about the same as above, *i. e.*, 95.8 cents per 1000 cu. ft., 26.2 cents per 1000 cu. ft. and 25.0 cents per 1000 cu. ft. We can see from these figures, that producer gas is the cheapest fuel, because there is no district in the East any more where natural gas is sold for industrial purposes for less than 30 cents per 1000 cu. ft.

Where the price for oil is small and that for coal high, the figures will tell a somewhat different story. The calculation, based on a cost of 4 cents per gallon for oil and of $5.00 per ton for coal, give, for an assumed equivalent consumption of 1,500,000 cu. ft. of natural gas per day, the following equivalent values for natural gas: from oil 37.1 cents, from gas from hand-poked producers 30.1 cents, and from gas from mechanical producers 29.5 cents, all per 1000 cu. ft. The corresponding figures for the smaller plant are 40.0 cents, 33.7 cents and 32.6 cents, respectively. These figures show that with a decrease in the cost of oil and an increase in the cost of coal the difference in operating expenses between oil and producer gas plants will become less and, for a certain price for oil, a price for coal can be determined for which the operation of a producer gas installation would cost more than that of an oil installation. In our case this point would be reached, when coal is $6.25 per ton, oil costing 4 cents per gallon.

The above proves that producer gas is, in most cases, the cheapest fuel for glass factories, no matter if it is generated in hand-poked producers or in automatic producers.

My experience has shown me that many of the men in charge of medium- or small-sized glass plants are not at all familiar with the application of producer gas. In many cases I have found that they are actually afraid to use it. It is hard for anyone, after having been accustomed to natural gas for all these years, to have now to resort to a fuel, quality and quantity of which seems to be beyond their control. It is true, natural gas is, or rather was, the most ideal fuel in existence, while producer gas is man's work with all the defects connected with it. But we might as well make up our mind that the times of the natural gas are passed, never to come back again. Compared with natural gas, producer gas is a good fuel, or, taking into account the loss in heating value of natural gas, due to the extraction of gasolene, it is even a better fuel than the present natural gas. All depends on the design of the plant and on the care with which producers, gas lines and furnaces are handled. Frequently, unsatisfactory working of the furnaces is blamed on the producer gas, while it is actually due to an improper design of the furnace itself or to carelessness in regard to the application of the gas; for it must be kept in mind that a furnace which is designed along the lines for burning natural gas, can not and will not burn producer gas efficiently and satisfactorily.

In the following is given an outline of the layout of a plant designed for producer gas and some data in regard to handling it:

Types of Producers

The first question that may arise when contemplating the installation of gas producers is: What type of producers should be selected? This depends, to a large extent, on local conditions, *i. e.*, on conditions prevailing in the factory under consideration. As the operating cost is practically the same for both types, the first cost is of considerable influence. If the men available for operating the producers are common laborers, there is no use for installing high-grade automatic producers. This would, be about as bad as giving a man, who has never run anything

else but a small steam engine, charge of a modern, high power gas engine. The result would be the same in both cases, the machinery would get out of order in a short time, thus causing trouble and expense to the management. On the other hand, where the manager is willing to pay the higher first cost and where a superintendent with technical experience can take charge of the producer plant, mechanical producers should be installed. Hand-poked producers, when handled right, will answer the purpose to a certain extent, but they are too much under the influence of the human element.

Charging a producer will change the composition of the gas, its quantity, pressure and temperature, that is, practically everything which is variable. Conditions can be improved by charging small quantities of coal in short intervals, but this is, in many cases, too much work for the gas maker, or better laborer. He rather dumps two hoppers full at once and then sits down for a half hour. This procedure is wrong; it will be made worse if two or three producers are charged at the same time. The influence of charging on the temperature of the gas leaving the producer can be seen from the curve, figure 2. The temperature drops about 500° F. in 5 minutes, and it takes about 15 minutes to come up to normal again. If there are 6 or 8 producers in a plant, this drop in temperature would not be noticed very much, if only one producer were charged at the time. But, on the other hand, if there are 6 producers, and 10 minutes would elapse between charging, one producer would be charged once an hour and that interval is too long. It is, therefore, necessary to charge two or three producers at the same time and, for this reason, the influence of the temperature drop will be noticed in the furnace. All this trouble can be eliminated through the installation of mechanical producers. Due to the continuous coal feed and the continuous ash removal, they furnish a gas of a more uniform quantity and quality, temperature and pressure, besides generating gas with a better heating value than gas made in hand-poked producers, while the influence of the human element is reduced to a minimum. The mechanical producer is, furthermore, a labor saver, where more than two units are installed; but it frequently saves labor with even two units. Need-

less to say, for all types of producers the best working conditions for the coal available should be determined, and the producers should then be operated accordingly.

Another advantage of mechanical producers over hand-poked producers, which came to the front during the last year and a half, is that they can gasify low grades of coal better than the other type. Formerly, and until the summer of 1917, the in-

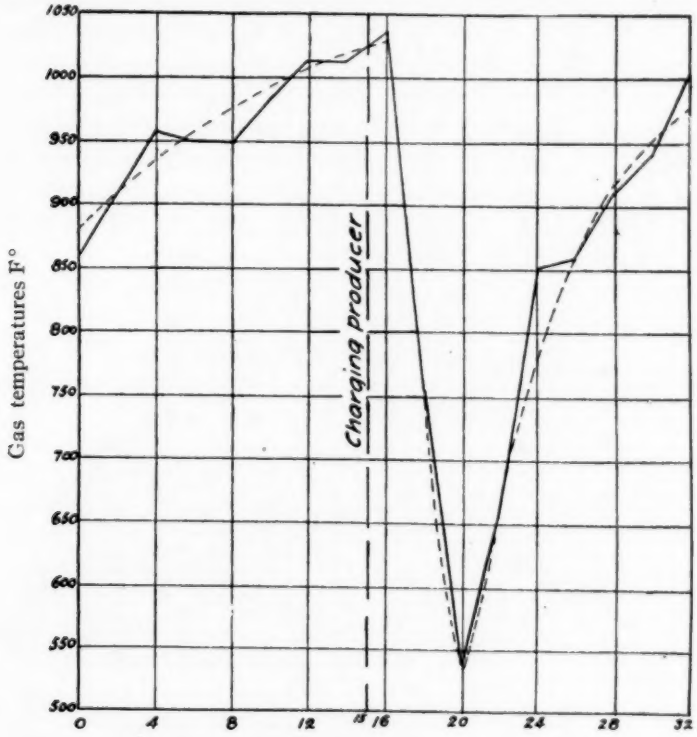


FIG. 2.—Curve showing influence of charging the producer on the temperature of the gas.

centive of competitve market conditions had maintained a practically uniform quality of the coal by special preparation. But from then on, the demand for coal was so insistent and the needs of the consumers were so pressing, that screening and washing

were largely abandoned; throughout the country the complaint was heard that coal was not being cleaned as in the past—that dirty coal was shipped. (U. S. Geol. Survey, Coal in 1917, part A, page 943.) I know this from my own experience to be true. According to the above statement, we now get a lower grade of coal than we used to get, and this lower grade is hard to gasify in hand-poked producers; but it can be gasified in mechanical producers. Taking, therefore, everything into account, it is the cheapest under present conditions to install mechanical producers and to employ men who know how to operate them.

The different types of the producers gasify different quantities of coal. As a rule, a stationary, hand-poked and hand-fed producer of 10 feet inside diameter can gasify between 900 and 1000 pounds of coal per hour, provided it is in good hands. Mechanical or automatic producers of the same size can gasify between 3000 and 3300 pounds of coal per hour, while the semi-automatic types can take care of about 2500 pounds. These are figures from good average practice.

Location and Layout of Producer Plant

The location of the producer plant in regard to the factory should be such that the bottom of the fuel bed in the producer is at a certain distance below the level of the ports in the furnace. The rising column of hot gases acts as a chimney. This point must be watched carefully, for, on account of the constant opening of the working doors of the furnace, the stack has no effect on the producer. If the producers are located too high, the gas cannot enter the furnace and trouble will result, unless special precautions are taken, which, in turn, may mean an increase in the first cost.

When hand-poked producers are installed, the layout of the producer plant should be designed in such a way that it will be possible to supply each unit in the factory with gas from a separate battery of producers. This means, for instance, a battery of producers for a pot furnace, a tank, a group of lehrs, glory-holes, and so forth. The different batteries should, however, be cross-connected. It is not good practice to put up a number of producers and have them all feed into one main, from which the gas for the whole factory is taken. In such a case, if anything

happens to the gas main, the whole plant must be shut down, or if anything happens to one or two producers, the whole plant will suffer. But if each unit has its own battery and gas main, and the batteries are cross-connected, the arrangement will be flexible and an eventual partial breakdown of the producer plant will not be felt severely in the factory. The cross-connections should, of course, be closed during regular working conditions.

For mechanical producers, the arrangement should be the same in principle, although it may differ in detail from the one described before. On account of the high rate of gasification, a mechanical producer is able to supply gas to more than one unit. The layout, therefore, can be designed in such a way that the gas required by one unit and the necessary lehrs and glory-holes, or whatever other accessories may be depending on the working of the furnace or tank, can be generated in one producer of required size. But here again cross-connections should be provided to help along in case of an accident.

The above holds good, of course, in plants of larger size only, having several tanks or furnaces, or both; for small plants, which may need only one producer, it is well to have a spare producer, to be protected against an eventual breakdown of the producer in operation.

With automatic producers the operation is practically entirely dependent on the machinery, and the operators' attention should be directed mainly towards the upkeep of the mechanical parts. The personal equation, therefore, has not as much influence on the gasification of the coal as is the case with hand-poked producers, where it is a very important factor. For this reason a few words may be said about the operation of this type of producers.

Increasing the Efficiency of Producers

Conscientious and careful attention on the part of those in charge of the plant will increase the efficiencies of the producers. It is a well-established fact that poor results, obtained in one plant as compared with another, are often almost entirely due to carelessness. On the other hand, it must be borne in mind that sometimes conditions exist beyond the producers which materially alter the results. Especially should the gas lines have watch-

ful care, that dust accumulations do not obstruct pipes and valves. Cleaning attachments should be carefully located for the convenience and least labor of the attendants.

Simple water gauges will often be a useful guide, when registering the pressure of the gas at the outlet of the producer or on the system; this is especially necessary where an inspection is made only at irregular intervals. At the gas outlet the pressure should be between 1 and $1^1/_2$ inches of water column. In all cases, frequent analyses of the gas should be made, so that the factors governing the working of the producers can be determined and properly regulated. The amount of carbon dioxide (CO_2) in the gas should not be more than between 5 and 7 per cent.

It is not right to increase the gasification by simply opening the steam valve, thus increasing the pressure and the amount of steam blown. It is true, this will give more gas, but gas of inferior quality. The amount of steam blown should not be more than is required for preventing the formation of clinkers.

A thick fuel bed can be maintained, when the ash bed is kept low by cleaning out the producers in regular intervals. Cleaning should be done at least once a day; but if conditions demand, it should be done whenever necessary. The cleaning reduces the dead resistance in the ash bed, which acts against the entrance of the air, while the useful resistance in the fuel bed will be increased, allowing us to carry a thicker bed of incandescent fuel. The ash bed should be brought to a point 6 or 7 inches above the top of the blast hood and should at no time approach nearer. Neglect of this precaution may cause the loss of the blast hood. The thickness of the fuel bed should be between 2 and 3 feet.

Among the most common sources of trouble in the operation of hand-poked producer are irregular charging and neglect of the operator to close up the channels, which permit air to ascend freely and which are sure to form in the fuel bed of hand-poked producers. The air, thus admitted to the top, will cause the gases to burn within the producers, making lean gas for the furnaces. The same result will be produced by too thin a fuel bed, which also will allow the air to pass through and combine

with the combustibles in the producer gas instead of with the combustibles in the coal.

The gas lines must be of ample size to enable the gas to reach its destination without serious obstructions. On the other hand, the diameter must not be made too large, as this will retard the velocity of the gas. Near the producers and wherever there is a change in the direction of the flow, dust catchers must be provided to take care of the soot, which will be deposited at those places. Soot will always be in the gas, but a gas maker who understands his business will see to it that he gets as little of it as possible. I have seen gas lines which were clogged up in three days to such an extent that no gas could pass through them at all; and I have seen other ones where a blowing out every noon removed all the soot that was in them and that amounted to only a wheelbarrow full for each producer.

A procedure very often resorted to for cleaning the lines is "burning out." This procedure, in my opinion, is wrong, as it will damage the lines; besides, it is not necessary. If the gas is made right, the amount of soot will be small; and if the lines are designed right, this small amount of soot will be deposited in the dust catchers. Whatever little quantities will settle in the lines can be blown out once a day, thus eliminating all burning out of the gas mains. The blowing should be done by means of air rather than by steam. When steam is used, it will, with the soot and tar, form a solid cake in the lines, which is hard to remove. With air this trouble is eliminated.

The question of overhead or underground gas lines depends on local conditions. As a rule, an underground line is cheaper than an overhead line of the same capacity. The underground line has the further advantage that it does not allow the gas to cool as rapidly as an overhead line, which is exposed to atmospheric influences. Temperature readings taken on an overhead line of 150 feet length showed a maximum difference of 500° F between the producer and the furnace, while on an underground line of not quite 100 feet length this difference amounted to only 60° F. If conditions do not allow the putting in of an underground line, the location of the producer plant in regard to the factory should be such that the overhead lines will be as

short as possible. This must be done to save a considerable part of the sensible heat in the gas. If the lines are built according to the rules laid down above, there will be no reason why the factory should not always get enough gas, provided the producers are well taken care of.

Regenerating Chambers

The gas is to be used in furnaces and tanks after regeneration and directly in lehrs, glory-holes, flattening furnaces, etc. The regeneration takes place in the checker chambers. These chambers, therefore, form a very important part of the furnaces and tanks. I have stated in the beginning that direct-fired furnaces, when using coal, either as such or in a producer built near the furnace or forming an integral part of it, are wasteful. Not withstanding this fact, furnaces with a direct coal fire are still in use and some have lately been designed and built for producer gas without regenerating chambers. It is true, a furnace will work under these conditions, as the gas comes in hot, having no chance to loose its sensible heat, and thus gives, even with cold air, the necessary temperature of combustion. But the saving in first cost, due to the elimination of the cl ecker chambers, is more than offset by the higher operating cost and the iess satisfactory working of the furnace. I will show, in one example, the difference in coal consumption for a furnace which was first operated direct with producer gas but which later was changed for regenerating the gas. For the direct firing, three 8-foot producers were required to furnish the gas, gasifying between 14 and 15 tons of coal per 24 hours. The producers had to be poked heavily all the time. After the furnace had been changed, only two 8-foot producers were necessary, gasifying a maximum of 8 tons per 24 hours total. This shows plainly the saving effected by a regenerative furnace. A direct-fired producer-gas furnace will work—there is no doubt about that—but with how high an expense and with how much trouble? That is the question which must be taken into consideration seriously.

In a direct-fired furnace, working with a temperature of about 2650° F, there is a maximum heat utilization of only 30 per cent. The installation of regenerating chambers increases this heat utilization considerably, and many a furnace builder guarantees

to the glass industry a saving of fuel of 60 per cent, which is not excessive. The difference in coal consumption for different types of glass furnaces may be seen from the data below:

A direct-fired furnace, without any regenerating chambers, uses from 2 to $2^1/_2$ pounds of coal for every pound of glass melted. This figure is reduced to the equivalent of $^1/_2$ to $^3/_4$ pound of coal for every pound of glass in a furnace fired with natural gas, having single regeneration only, that means, having only regenerating chambers for the air. In producer gas-fired furnaces I have seen coal consumptions of $^1/_3$ pound of coal per pound of glass, the furnaces having double regeneration, preheating the air and the gas. This last figure is not taken from a "show test," but from daily record sheets.

The checker chambers have to answer a two-fold purpose. In the first place, they have to serve as a means to transmit the surplus heat from the waste gases to the incoming gas and air, in order to enable these agents to generate the necessary heat in the furnace. But they must provide also an easy passage for the incoming gas and air and for the outgoing waste gases, without which easy passage it is not possible to operate the furnace and tank satisfactorily and efficiently. This second purpose has too often been neglected, with the result that the life of the furnace has been shortened to a considerable extent. It must, however, be kept in mind that it is not possible to build the checker chambers in such a way that they will serve both purposes simultaneously in the most efficient manner. This can easily be understood, when we consider the following:

In order to absorb as much heat as possible from the waste gases and transmit as much heat as possible to the incoming gas and air, the checker bricks should be laid in such a way that they present as much surface to the gases as possible. This can be done either by laying the bricks close together or by laying them staggered, that means, by laying them so that the small channels, which are formed by the bricks, run in a broken line instead of in a straight line. But such an arrangement, although of benefit to the heat transmission, would prevent a free and undisturbed passage of the gases, because it would form obstructions or restrictions in the passageways.

On the other hand, if the checker bricks are laid with the intention of providing free and easy passages for the incoming and outgoing gases, they would have to be laid far apart and would not be fit to perform their other duty, that is, absorbing and transmitting the heat. We see that in laying out the checker chambers we have to follow the happy medium, in order to get the best results obtainable.

There is another claim made in regard to the disadvantage of using checker chambers. This claim is based on the dissociation of the gas when exposed to high temperatures. It holds true for natural gas, but it does not hold true for producer gas under the conditions prevailing in glass factories. At high temperatures the heavy hydrocarbons, contained in natural gas as well as in producer gas, will be decomposed. For natural gas, containing from 95 to 98 per cent of these constituents, this decomposition would be detrimental; and for this reason natural gas-fired furnaces have regenerating chambers for air only. For producer gas, however, the decomposition would not be of very much influence, as this fuel, in most cases, contains only 3 or 4 per cent of heavy hydrocarbons. The loss in heating value would be small and the small amount of soot, deposited in the checkers and coming from the decomposition, would easily burn out and would not clog the channels, as would be done by the large amount of soot remaining from the decomposition of natural gas, if it ever were tried to preheat this fuel. A high temperature in the checkers is, therefore, harmless for producer gas, as can be seen in any open-hearth furnace; but in glass furnaces, the temperature in the checker chambers is seldom so high that the hydrocarbons will be decomposed. In most all cases, this temperature remains below 1500° F; and it is at this temperature that decomposition starts. There is, for this reason, no cause for distrust against using regenerative furnaces on the part of the glass factory managers.

Gas and air before entering the furnace and the waste gases after leaving the furnace have to pass through a set of reversing valves, the size of which must be determined to suit the conditions. Too small or too large openings are detrimental to the correct working of the furnace, as they influence the flow of the

gases. A glass furnace has these reversing valves in common with an open-hearth furnace in a steel plant; but as the ruling temperature in our case is only about 2650° F, there is no need for a large number of regulating dampers, which are necessary for an open-hearth furnace, having a ruling temperature of about 3100° F. A stack damper must, of course, be provided.

It may be well to point in this connection to an idea which is entertained by many a glass house superintendent. If they are reminded of the extended application of producer gas in the steel industry, they invariably will answer: "But a steel furnace is something entirely different from a glass furnace." There is no reason for such an answer at all. A regenerative furnace is a regenerative furnace, no matter for what it is used, the only difference between the two types being the temperature required in the hearth. If it is possible to obtain 3100° with producer gas in an open-hearth furnace, it must be possible to obtain 2650° with the same fuel in a glass furnace, as long as the furnace is built right. And right here is the point which is neglected in many cases. It is true, some furnaces do not work the way they should work, but the blame is laid on the fuel and not on the furnace. If the gas is made right, if the furnace is designed and built right and if it is watched carefully, it must give good results, provided the stack is of the right size.

Size of Stacks

This stack proposition is another item which is often neglected. The dimensions of many of these stacks are designed according to Kent's well-known tables of boiler stacks. A boiler stack, however, cannot be compared with a furnace stack, and this table should, therefore, not be used at all. An example will prove this statement. Supposing we have a furnace using an equivalent of 250,000 cu. ft. of natural gas per 24 hours. The stack dimensions from Kent's table are: height 90 feet, mean diameter 39 inches, while they should be: height 112 feet, mean diameter 66 inches. This difference is too large to be neglected. Every furnace should be provided with its own stack, as the regulation of the draft is then made easier and more effective.

Use of Producer Gas in Lehrs

The only place where there would be any reason for refusing to use producer gas would be in the lehrs and glory-holes and in similar furnaces. Due to the way these appliances are built producer gas cannot be burned in them without sulphuring the ware, thus either increasing the cost of production, as the thin white coating has to be washed off, or making the ware valueless, when this coating is too thick to be washed off. To overcome this trouble in lehrs, muffles have been designed, which are intended to keep the ware protected from the flame. But, are these muffles necessary? I have seen open lehrs fired with coke, which contains sulphur, yet the ware was clear; I have seen open lehrs fired with natural gas in which the ware was highly sulphured; and I have seen open lehrs fired with producer gas which did not sulphur. Why should producer gas sulphur the ware, if coke does not do it? It all depends on the correct design; if this is right, there will be no trouble from sulphuring when using producer gas.

Conclusion

Concluding, I want to say, that there is at the present time no necessity for the glass factory managers to be afraid of using producer gas as fuel. If the right type of producers is installed, if the whole plant is laid out right, and if the furnaces and the other appliances are designed and built right, producer gas will not only be as good a fuel as natural gas, but it will be a better fuel, besides being cheaper than natural gas in all cases, and cheaper than fuel oil in many cases.

Appendix

Comparative Calculation of First Cost and Operating Cost for Fuel Oil and Producer Gas

The following calculations are based on a daily consumption of 1,500,000 cu. ft. of natural gas and of 500,000 cu. ft. of natural gas. For simplicity's sake, we will assume 10 cu. ft. of natural gas to be equivalent to 1 pound of coal, and 140 cu. ft. of natural gas to 1 gallon of fuel oil.

A. Large Plant

Daily consumption of natural gas.....	1,500,000 cu. ft.
Corresponding consumption of oil.....	11,000 gallons
Corresponding consumption of coal.....	75 tons

1. First cost of fuel oil plant

8–10,000 gallon storage tanks, at $1700.00 each	$13,600
Foundation, erection and so forth	1,000
Circulating pumps and motor	500
Piping, valves, fittings and air connections	10,000
Connections to furnaces, burners and so forth	6,300
Pumps and other appliances, blowers, motors and blast connections	5,000
Total	36,400
Say	$36,500

The gas producers gasify 75 tons of coal per 24 hours or 6250 pounds of coal per hour. Figuring on an installation of hand-poked producers with a capacity of 1100 pounds of coal per hour, we need 6 producers. Counting one extra for spare, makes 7 producers.

2. First cost of gas producer plant with hand-poked producers

7–10 feet i. d. producers, at $2,000 each	$14,000
Buildings, foundation, excavation, erection, freight and so forth	14,000
Coal crushing and conveying machinery	6,000
Coal bunkers	6,500
Steam and water piping along producers	2,500
Overhead flues, valves and so forth	3,500
Total	$46,500

For mechanical producers, or gas producer machines, having a capacity of 3300 pounds of coal per hour, we have to install 2 producers. Figuring again on one for spare, makes 3 producers.

3. First cost of gas producer plant with mechanical producers

3–10 feet i. d. producers, at $12,000 each	$36,000
Building, foundation, excavating, erection, freight and so forth	14,000
Coal crushing and conveying machinery	6,000
Coal bunkers	4,000
Steam and water piping along producers	2,500
Overhead flues, valves and so forth	3,000
Total	$65,500

The operating cost is figured for a day as unit and contains the fixed charges.

1. Operating cost for a fuel oil plant

Interest, depreciation, taxes and insurance at 16 per cent per year of $36,500	$ 16.00
Fuel oil, at 11 3/4 cents per gallon, 0.1175 × 11,000	1292.50
Labor, 16 men total, 2 shifts, 45 cents hour	86.40
One foreman	7.00
Electric current, air, and steam	6.50
Lubricating oil, waste and so forth	1.00
Total	$1409.40 per day

2. Operating cost for a gas producer plant, hand-poked producers

Interest, depreciation, taxes and insurance at 16 per cent per year of $46,500	$ 20.38
Coal, 75 tons, at $3.50	262.50
Labor, 11 men total, 2 shifts, 45 cents hour	59.40
One foreman	7.00
Steam and water	6.00
Total	$ 355.28 per day

3. Operating cost for a gas producer plant, mechanical producers

Interest, depreciation, taxes and insurance at 16 per cent per year of $65,500	$ 28.71
Coal, 75 tons, at $3.50	262.50
Labor, 6 men total, 2 shifts, 45 cents hour	32.40
One foreman	7.00
Steam and water	6.00
Oil and waste	0.50
Current for motors	3.00
Total	$ 340.11 per day

Cost for natural gas
1,500,000 cu. ft. at $0.32/1000 cu. ft ..... $ 480.00 per day

The equivalent cost for natural gas is

in the case of oil	cents 94.0 per 1000 cu. ft.
in the case of producer gas	
from hand-poked producers	cents 23.7 per 1000 cu. ft.
from mechanical producers	cents 22.7 per 1000 cu. ft.

Figuring on a cost of oil of 4 cents per gallon, and on coal of $5.00 per ton, the corresponding figures would be:

Operating cost	
for the oil plant	$556.90 per day
for the producer plant	
with hand-poked producers	457.78 per day
with mechanical producers	442.61 per day
and the equivalent cost of natural gas	
in the case of oil	cents 37.1 per 1000 cu. ft.
in the case of producer gas	
from hand-poked producers	cents 30.1 per 1000 cu. ft.
from mechanical producers	cents 29.5 per 1000 cu. ft.

B. Small Plant

Daily consumption of natural gas	500,000 cu. ft.
Corresponding consumption of oil	3,600 gallons
Corresponding consumption of coal	25 tons

1. First cost of fuel oil plant

3–10,000 gallons storage tanks, at $1700 each	$ 5,100
Foundation, erection and so forth	375
Circulating pump and motor	300
Piping, valves, fittings and air connections	5,000
Connections to furnaces and so forth	2,100
Other appliances	3,000
Total	15,875
Say	16,000

2. First cost of gas producer plant with hand-poked producers

3–10 feet I. D. producers, at $2000 each	$ 6,000
Building, foundation, excavation, erection, freight and so forth	6,000
Coal bunker	500
Steam and water piping along producers	2,500
Overhead flues, valves and so forth	3,000
Total	$18,000

3. First cost of gas producer plant with mechanical producers

1–10 feet I. D. producer	$12,000
Building, foundation, excavation, erection, freight	5,000
Coal crushing and conveying machinery	5,000
Steam and water piping along producer	1,000
Overhead flues, valves and so forth	2,000
Total	$25,000

1. Operating cost for a fuel oil plant

Interest, depreciation, taxes and insurance at 16 per cent per year of $16,000	$ 7.00
Fuel oil, 3,600 gallons at 11¾ cents gallon	423.00
Labor, 8 men total, 2 shifts, 45 cents hour	43.20
Electric current, air and steam	5.00
Lubricating oil, waste and so forth	1.00
Total	$479.20 per day

2. Operating cost for gas producer plant with hand-poked producers

Interest, depreciation, taxes and insurance at 16 per cent per year of $18,000	$ 7.89
Coal, 25 tons at $3.50 ton	87.50
Labor, 6 men, 2 shifts, 45 cents hour	32.40
Steam and water	3.00
Total	$130.79 per day

3. Operating cost for gas producer plant with mechanical producer

Interest, depreciation, taxes, insurance at 16 per cent per year of $25,000	$ 10.96
Coal, 25 tons, at $3.50 ton	87.50
Labor, 4 men, 2 shifts, 45 cents hour	21.60
Steam and water	3.00
Current for motor, waste and so forth	2.00
Total	$125.06 per day

Cost for natural gas
500,000 cu. ft. at $0.32/1000 cu. ft. $160.00
The equivalent cost for natural gas is
in the case of oil ..... cents 95.8 per 1000 cu. ft.
in the case of producer gas
from hand-poked producers ..... cents 26.2 per 1000 cu. ft.
from mechanical producer ..... cents 25.0 per 1000 cu. ft.

Figuring again on oil for 4 cents gallon and on coal for $5.00 per ton, the corresponding figures are:

Operating cost
for the oil plant ..... $200.20 per day
for the producer plant
with hand-poked producers ..... 168.29 per day
with mechanical producer ..... 162.56 per day

The equivalent cost of natural gas is
in the case of oil..... cents 40.0 per 1000 cu. ft.
in the case of producer gas
from hand-poked producers..... cents 33.7 per 1000 cu. ft.
from mechanical producer..... cents 32.5 per 1000 cu. ft.

Table Showing Cost for Oil and Producer Gas

Daily capacity of plant: 1,500,000 cu. ft. of natural gas

			Oil 11¾ cts. per gal. Coal $3.50 per ton		Oil 4 cts. per gal. Coal $5.00 per ton	
	Kind of fuel	First cost $ and %	Operating cost $ per day and %	Equiv. cost of nat. gas Cts. per 1000 cu. ft.	Operating cost $ per day and %	Equiv. cost of nat. gas Cts. per 1000 cu. ft.
	Oil	36,500	1409.40	94.0	556.90	37.1
		100%	100%		100%	
Producer gas from	Hand-poked producers	46,500	355.28	23.7	457.79	30.1
		127.4%	25.2%		82.2%	
	Mechanical producers	65,500	340.11	22.7	442.67	29.5
		179.4%	24.1%		79.5%	

Daily capacity of plant: 500,000 cu. ft. of natural gas

	Oil	16,000	479.20	95.8	200.20	40.0
		100%	100%		100%	
Producer gas from	Hand-poked producers	18,000	130.79	26.2	168.29	33.7
		112.5%	27.3%		84.1%	
	Mechanical producers	25,000	125.06	25.0	162.56	32.5
		156.3%	26.1%		81.3%	

NOTES ON TERRA COTTA SLIPS WITH REFERENCE TO THE USE OF ASBESTOS AND CHLORITE MICA

By Hewitt Wilson

Introduction

History.—Since the beginning of terra cotta work in this country in 1853, there has been a constant demand and considerable search for new methods of decoration. And while there have been changes in the character of the molding and body ornament, the greatest changes have been made in the exterior protective coatings. To quote Doctor Ries "Most of the earlier terra cotta did not have its surface covered with a coating and protective slip * * * * although the practice became widespread about 1884. The dull texture vitrified slips were the first coatings used. Full glazes were not introduced commercially until 1897." Mat glazes and polychrome decorations are of comparatively recent origin. At the early dates the surface was often decorated with markings and colors to match the building stones used in conjunction with the terra cotta.

Notwithstanding the fact that terra cotta is being made in highly colored decorations, the body underneath the coating is very similar to those of earlier dates. In fact because cone 8 was a common temperature for burning terra cotta, some of the older and, it is true, darker colored bodies have shown better weathering qualities than many of recent production.

Classification.—At the present time we can divide the terra cotta manufactured in this country into three general classes, high-, medium- and low-fired. High-fired ware is that fired to cones 6–7: medium-fired is that fired to cones 3–4; and low-fired ware is that burned below cone 3, usually in the neighborhood of cones 01–3. Classified according to the character of the exterior coating we have two general classes, vitrified coatings and glaze coatings. The original vitrified coatings were composed of natural slip clays and were usually buff, brown or red in color.

These natural clay slips, blended with more or less fluxing material, are still used to a considerable extent for producing the darker colored vitrified coatings. When light grays were wanted, it was necessary to use slips similar to porcelain or earthenware bodies slightly colored or spotted according to the color and grain of the stone to be matched. For the present day high-fired terra cotta, vitreous, ink-proof, white slips can be produced with mixtures of feldspar, ball clay, kaolin, flint and Cornish-stone as a base. But for the lower temperatures, especially below cone 4, the addition of fritted fluxes is a common practice.

For glaze coatings, the bristol glaze with its later addition of barium, magnesium and tin oxides, has served for firing above cone 4, while fritted glazes are used below that heat. Salt glazing has been used to a limited extent.

Vitrified Slip Coatings

From this general survey we wish to center our attention on those white or light gray vitrified slip coatings fired to about cone 6. They are called "standard finishes" or "vitrified slips." As to the preparation, they are either churned by paddles revolving in a stationary tank, blunged in a revolving barrel mill with but few pebbles, soaked and blunged by hand, or ground like a glaze in a regulation ball mill.

Defects of Vitrified Slips.—Comparatively speaking, there is very little trouble due to peeling, that is, a separation of the slip from the body. The clay content is usually high enough to provide proper adhesion to the body underneath. However, a great many vitrified slips which show good adhesion when used alone will show poor holding qualities when covered with a glaze, or, in other words, when the slip is used as an underslip.

Variations in color are usually caused by variations in the thickness of the coating, variations in the burning treatment, such as uneven temperature or flashing, and the use of a slip which verges too close to complete fusion, such as is obtained by an excess of fluxing material. In this case the usual variations in heat distribution will cause marked differences in shade and color. Coloring ingredients, such as iron and manganese, volatilize to a certain extent in the firing, and uneven burning condi-

tions will cause variations in color. Uniformity of color places terra cotta in a distinctive class of ceramic ware. The surfaces are large, the individual units are grouped together in the wall of a building, where, under changing lights and observation from all angles, any off-colored units will stand out distinctly. Moreover, the uniformity of color depends on a coating about two-hundredths of an inch thick to hide a buff-colored body.

Cracking is due to a number of causes. It may be due to the fault of the slip itself or to the body beneath. When due to the former, it is usually the result of faulty composition or too heavy spraying. Any slip will show drying or burning cracks when it is applied in too heavy a coating. It is a great temptation for the sprayer to add a little more slip and be sure there is enough on the surface. Cracking in the ornament or internal angles likewise may be due to flooding the angle with wet slip.

A Typical Composition.—In order to avoid undue confusion we have selected a single slip which has been in use in a terra cotta plant for a number of years as a standard finish or vitrified slip. It may be used for whites or light grays or as a base for colored slips. The composition is as follows:

COMPOSITION K

Flint	20 per cent
Cornish stone	45
English china clay	25
English ball clay	10
	100

This is very similar to the formula given in *Trans. Am. Ceram. Soc.*, **16,** pp. 163 and 169 (1914), by Coats and Phillips, who worked under Professor Binns. In these articles there is about 12 per cent ball clay, half English and half German. Here it was used as an underslip, that is, covered with glazes.

This slip has slight absorption when burned to cone 6–7. Although showing very good adhesion when used alone, it gives poor holding qualities when covered with a glaze at this temperature. Not that it shows peeling, but it gives a very easy separation from the body when the glazed surface is tapped with a chisel.

However, it has been used for commercial work as an underslip. If cracks develop in drying this slip, there will be no healing or mending during the burning process. It is practically free from cracking on a smooth or tooled surface when properly sprayed on body A. Considerable trouble is experienced from small surface cracks when this slip and many others are sprayed on terra cotta body B.

The following screen analyses were made on a blunged sample of each of the above-mentioned bodies.

	—Body A—		—Body B—	
Plus 20 mesh	2.4	4.6	4.3	10.7
20–40 mesh	8.2	16.3	12.7	31.8
40–100 mesh	20.0	39.8	9.5	23.8
100–200 mesh	9.6	19.1	6.0	15.0
Residue	10.1	20.2	7.5	18.7
Total non-plastic	50.3	100.00	40.0	100.0
Approximate clay content	49.7		60.0	
	100.0		100.0	

Body A is composed of a mixture of soft plastic and sandy clays with 20 per cent grog. Body B consists of about 40 per cent grog with a mixture of soft clays, all of which show negligible amounts of residue on a 200-mesh sieve. The former has a shrinkage of about $^{7}/_{8}$ inch and the latter about 1.0 inch to the foot.

The Relation between Grog in a Terra Cotta Body and the Slip Coating

General Relations.—It may be said that the coarser the grog the greater will be the size of cracks in the slip coating; and the greater the number of coarse grog particles the greater the number of cracks. With the above slip, bodies containing grog which will pass a 65-mesh sieve seldom show cracking on plane or tooled surfaces which have not been mistreated. Grog particles which will be retained on a 65-mesh sieve are liable to cause surface cracks, the danger increasing with the number and size of the larger grains.

Seven bodies containing grog screened to the following sizes were made: 16–20, 20–30, 30–35, 35–48, 48–65, 56–100, less

than 100. The trial pieces gave very bad cracking with sizes above 30-mesh, and a moderate number of fine cracks with grog sizes between 30–65 mesh. The cracking is practically eliminated by reducing the size of the grains below 65-mesh.

It is out of the question to screen terra cotta grog to pass a 65-mesh screen or even a 30 mesh, because of the cost plus the danger of warping, cracking or dunting in the body on cooling. For discussion on dunting see *Jour. Am. Ceram. Soc.*, **1**, pp. 193–200. The majority of terra cotta grogs in use show at least a few per cent caught on a 20-mesh screen.

Effect of Coarse Grog.—If a plastic clay is mixed with coarse grog gains alone, for example, those caught between a 16- and 20-mesh, and the latter be evenly distributed throughout the body, a representative portion will be contained in the surface layer. Grog grains of this mesh are about 0.04 of an inch in diameter. If the piece has been finished the plastic clay will cover all parts of the surface grains, save projecting edges, which cannot be seen but can be felt and heard when a steel finishing tool is drawn across the surface. As the plastic clay between the grains shrinks in drying and burning, it will form depressions between these large grains. The surface will be roughened, and even the dry piece will show many cracks across the particles whose projecting edges have acted like wedges and split the clay mass as soon as a certain degree of brittleness developed. When the slip coating is sprayed on this dry surface, the water causes a swelling of the upper layer. This expansion is followed by another shrinkage. The disturbance produces even greater disruption on the surface, so that the usual slip, trying to adjust itself to the irregular surface, is likewise cracked.

Now if a grog mixture of the usual mechanical analysis is substituted for the uniformly coarse grains, the shrinkage of the plastic mass between the large grains will be reduced, the surface will be smoother and the cracking of the slip coating will be less. But as long as there is a plastic shrinkage mass between the large grains there will be a tendency to crack.

Here is a wide field for study—the determination of the proper proportion of sizes which will give the least surface trouble together with the best strength and ability to withstand tempera-

ture changes. A method similar to that used by Kirkpatrick[1] for fire clay and grog mixtures could undoubtedly be followed. Of course, different clays will show different results in this respect with the same grog mixture, so it is an individual problem after the principle has been established. It is believed that those clays showing the greater dry and burned transverse strength will be less liable to this trouble.

Action of Water on the Dried Surface.—By wetting the surfaces of the bodies containing the various sizes of grog we found that after repeated treatments, the surfaces containing grog caught on a 65-mesh sieve were more disturbed by the water than the finer sizes. This swelling and consequent shrinkage caused by the action of the water in spraying may have the same result as freezing and thawing soil, which tends to push out the hard particles embedded in it, such as stones, posts and stakes.

Hardness of Grog *versus* **Sizing.**—If the grog particles above 65-mesh are liable to cause cracking, care should be taken to maintain a uniform proportion of these troublesome sizes in order to produce uniform results. Using the same grinding machinery and the same mesh screen, different grog mixtures of varying hardness will give different proportions of the various sizes of grain. The harder grog, *i. e.*, that which will not pulverize so easily and will produce less dust with the same crushing force, will contain more of the larger and troublesome sizes per unit. For example, if grog C were substituted for grog D, the

	Grog C	Grog D
Terra cotta	10	60
Fire brick	10	...
Pottery saggers	80	40
	100	100
Plus 20 mesh	11.9	3.6
20–40 mesh	36.0	33.4
40–100 mesh	23.4	29.3
100–200 mesh	10.3	15.0
Minus 200 mesh	18.4	18.7
	100.0	100.0

[1] Kirkpatrick, F. A., "Effect of Size of Grog in Fireclay Bodies," Bur. Standards, *Tech. Paper* 109.

increased number of the larger grains undoubtedly would cause more surface cracks. The pottery saggers in this case were much harder than the terra cotta.

Effect of Kind of Grog on Surface Cracking.—So far we have not been able to distinguish between hard and soft burned terra cotta, pottery sagger, fire brick and white ware if they were clean and ground to approximately the same screening analysis. The strength and absorption of these different bodies will vary however. The clause "ground to the same screening analysis" does not mean simply ground to pass the same mesh sieve, as these materials vary in hardness. Round silica grains, however, do cause more cracking due to the shape and to the movements caused by the volume changes of quartz when heated.

Relation of Pressing and Finishing to Surface Cracking

Method of Pressing.—Proper methods of pressing and finishing are essential to smooth, unbroken slip surfaces. The presser tears or cuts a lump of clay from the pile. If it is for the face of the piece, it is rolled and patted on a plaster board until the surface is smooth and the grog particles are covered. This bat is then thrown into the mold, smooth side of the clay next to the mold. If one is not large enough, other bats are slapped in until the face and sides are covered. Where the smoothed side of the clay bat lies unbroken on the plaster, it needs little further attention. However, at the union of the two bats, particularly where the smooth surface had to be broken to cover the plaster, the surface will be rough and groggy and needs further treatment. Thorough beating of the clay as it lies in the mold, before the partitions are built in, will eliminate the rough and broken places and cause the grog to leave the surface. You can often trace the outline of a bat of clay across the face of an ashlar on a poorly pressed piece by following the line of the surface cracks, which are the result of torn clay not properly smoothed.

Absorption of Water by the Mold.—If the clay has given up enough water to the mold, so that the piece can be "turned out" without distortion and bear its own weight, the face, which has lain next to the mold will be in a stiffened condition considera-

bly beyond its best plastic condition. The average of two trials gave us the following results, using dry plaster and clay masses of an inch thickness, covered with a glass plate:

Results with Body B	(*a*)	(*b*)	(*c*)
Time of contact between plaster and clay in minutes	10	20	30
Per cent water absorbed by plaster in terms of total water content	5.9	10.1	10.5
Per cent water absorbed by plaster in terms of dry weight of clay	2.5	4.3	4.4

And this water is not evenly distributed throughout the mass. The average of seven trials gave between 2.0 and 3.0 per cent (in terms of dry weight of clay) less water in a thin section about 0.05 of an inch thick which had been against the plaster than sections taken from the interior and the outer surface. Undoubtedly, the skin of clay immediately on the surface contains even less water and is approaching brittleness.

Drying.—As a clay mass dries from the best plastic state, it gradually loses its moldability and becomes more brittle, although its strength is increasing at the same time. In this latter state, as the plastic working properties decrease, the clay also loses the ability to adhere when broken faces are pressed together. This is probably a gradual change. The rate of loss of water and the minimum amount of water needed for plasticity or moldability are properties peculiar to each clay. The safe working range is undoubtedly less for bodies containing coarse non-plastics, such as terra cotta grog, than for bodies in which the non-plastic content is in the state of ground feldspar or flint.

Methods of Finishing.—After the mold is stripped off the piece of terra cotta, it is usually allowed to stand and dry or stiffen before finishing. This interval will vary from one to twenty-four hours or even more, depending on the practice which has been found best for the body. Of the two samples given above, 24 hours was a good interval for body A which lost its water very slowly, while body B should be finished as soon as possible, as it lost its water content very quickly and easily.

There are two general methods of finishing, also, combinations of the two: Finishing with "steel," such as a trowel or a special

tool for ornament, edges or tooled surfaces, and finishing with a water brush, which is equivalent to the sponging of pottery in the leather hard state. Preceding the water brushing, the edges, corners and lines of the piece are straightened and the surfaces cleaned of the larger irregularities.

Finishing with Steel.—Rubbing a smooth trowel over a piece of clay in its best plastic state is similar to pressing a column of clay through the die of a brick machine. It is a smoothing pressure, followed by a release. Exposed particles of grog are pressed down by actual contact with the tool while the plastic clay, with ability to flow, is squeezed up and around the grog grains until they are embedded, save for that point which is in contact with the tool. They are not completely buried; you can not see them easily, but you can feel and hear the grating or scratching as the tool passes over the surface.

If the clay mass has dried until brittleness and the consequent decrease in moldability have developed, the clay is torn as it is pressed up around grog grains or as the grains are moved slightly in a horizontal direction. Though pressed together, a great many of these torn surfaces are not firmly bonded again and the cracks are easily reopened by the stresses which accompany drying and burning. It is easier to smooth a surface approaching the leather-hard condition. It resists visible deformation and polishes easily. Naturally there is a tendency for a presser to delay finishing his ware until it reaches the state in which it can be done most easily and quickly.

Finishing with Water Brush.—A soft, flat brush is dipped in water and the excess water pressed out on the edge of the bucket. The surface is then rubbed thoroughly. This action knits the torn surfaces and fills the minute cracks, increases the water content of the surface so that there is less difference between the interior and the surface, and either picks up and removes or partially buries, in a firm plastic mass of clay, the exposed grog grains. Water brushing is more rapid than steel finishing, and it can be used for ashlar, plain or tooled finish and for ornamental work. A soft sponge may be preferable to a brush for delicate ornament. As in the case of steel finishing, if dryness has progressed beyond

a certain stage this method of soaking the surface is ineffective as a preventative of slip cracking. From an actual count of cracks on tooled surfaces of regular ware (body B), the ratio of cracks on steel-finished to those on water-brushed areas was greater than 4 : 1.

Our observations lead us to believe that, on the average, better surfaces are produced by a corp of trained finishers working by the day than by leaving the pressers finish their own ware, especially if they are on piece work. This places the responsibility of the production of good surfaces in the hands of a smaller group of specially trained men so that there will be less tendency to neglect this important factor.

The Relation of Spraying to Surface Cracking

Specific Gravity of Slip.—This is the weight of a given volume of slip divided by the weight of the same volume of water. A ground-glass stoppered bottle of about one pint capacity gives good service. With no alkali, a specific gravity of about 1.350 gives a good spraying viscosity. However, 0.5 per cent soda ash allows the water content to be reduced so that the specific gravity can be raised to 1.470 and still give a good spraying slip. With the decreased water content the results are quicker drying, less shrinkage, less water soaking into the surface of the body, and less tendency toward cracking. A piece can be coated in one operation so that it is not necessary to allow it to stand and dry. More care must be taken in spraying as it is easier to get the slip too heavy in this case, as there is more dry material per unit volume of slip.

Methods of Spraying.—To avoid the two common evils in spraying slips, *i. e.*, thin and thick spots, we would suggest the following procedure: After removing all loose surface material by blowing and brushing, blow the slip swiftly over the entire piece, filling all body inperfections, minute cracks and ornamental internal angles. Shut off slip, hold the nozzle close to the surface and blow it dry, removing all excess slip from the internal angles and cavities. This puts a coating of slip *all over* the surface and helps avoid the pink spots of bare body. To tone up the piece, the ashlar surfaces and the exposed portions of the ornament

may need an additional coating. This can be applied immediately with the gun held at a distance. Care should be taken to avoid wetting the internal angles at this time.

Dry spraying, *i. e.*, that in which a water finish does not form but where the water content is so slow that the slip is deposited on the surface as dust is not a good method for slips which do not fuse and smooth out in burning. The surface is still rough and porous after firing. This method has been successful for filling the internal angles of glazed ware.

Changes in the Composition of Vitrified Slip Coatings

While the above slip K gives good results on bodies containing fine grog there is always trouble with bodies containing large amounts of coarse grog or in bodies which are badly finished. This slip was changed so as to give greater elasticity or covering action so that the condition of the body has less influence on the slip. The slips described below were weighed, ground in a ball mill for two hours and screened through a 40-mesh sieve. Each member was sprayed on a piece of terra cotta which had a finished surface of at least 7.5 by 10.5 inches. Both plain and tooled ashlars were used. The samples were burned in commercial terra cotta kilns to cone 6–7.

Examination of Burned Samples.—The burned samples were examined with reference to the following points:

(1) Comparison of colors, surface texture, blisters, and so forth.

(2) **Absorption.**—Red ink was painted on a portion of each sample and allowed to stand for at least 10 minutes. All that could be removed was then washed off with soap and water.

(3) **Cracking.**—As many cracks are practically invisible without close inspection or the use of hand glass, each sample was washed with a slip of coal dirt and water. After a second bath in clean water, all the minute cracks are revealed. This practically duplicates the treatment to which most of the ware is subjected in the wall of the building. Many jobs are set in apparently first-class condition and later found to be full of small crows-feet and cracks.

(4) **Crazing.**—The red ink plus the dirty water reveals crazing and dunting cracks. How many of these larger cracks, *i. e.*, crazing and dunting, which appear after setting in the wall can not be found in the factory is yet a question to us. It is surprising what a little dirty water will reveal on an apparently sound ashlar.

Variations in Composition.—A complete substitution of Brandywine feldspar (soda) was made for Cornish stone in each of the following series: Each series consisted of eight changes from the original or nine members. The slips were sprayed over body B.

	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)
Flint	0	5	10	15	20	25	30
Soda spar or Cornish stone	45	45	45	45	45	45	45
Georgia kaolin	20	15	15	10	10	7.5	7.5
English ball clay	35	35	30	30	25	22.5	17.5
	100	100	100	100	100	100.0	100.0

Substitution of Brandywine Feldspar for Cornish Stone.—In each case as the soda feldspar increases, the color becomes grayer, for vitrification is increased and the translucency permits the body beneath to show. Likewise the gloss increases with the increase of Brandywine feldspar. There were no blisters. Practically the first four or five members of each series showed slight ink absorption and the last half of each series was ink-proof. This means that 22.5 to 45.0 per cent Brandywine feldspar plus 22.5 to 0.0 per cent Cornish stone gives more vitreous slips than those higher in Cornish stone.

Although there was an increase in vitrification with greater contents of Brandywine feldspar, yet the cracking was not diminished. An average of the group was about 300 per square foot.

Substitution of Flint for Clay.—*Color.*—A and B series containing 35 per cent English ball clay have a grayer or more creamy color than the rest of the series of lower ball clay content. There was a distinct sheen or gloss to the members containing high Brandywine feldspar and 25 to 30 per cent flint.

Absorption.—There was very little difference found between the members of high clay or high flint contents. Undoubtedly

with a great many trials, the highest English ball clay members would be the least absorbent.

Cracking.—There was a distinct difference between the series in which the flint content was 20 per cent or less and those of 25 and 30 per cent flint. For example, in the series F the cracking was as follows:

	F1	F2	F3	F4	F5	F6	F7	F8	F9
Number of cracks per square foot.....	255	73	22	64	75	55	13	15	5

In series G the number of cracks was at a minimum. The combination of Brandywine feldspar and at least 25 per cent flint gave a decided reduction of surface cracking.

Crazing.—While high soda feldspar and high flint gave a reduction in minute drying and heating cracks, the slips crazed badly on cooling. This was especially bad in the smaller kilns. It is a case of substituting one trouble for another. This crazing would cause series F and G to be discarded at once as unsuitable for commercial slips.

Miscellaneous Series.—A number of series were made using our original slip K containing 20 per cent flint. This combination has proved its practical value under one set of commercial conditions.

Substitution of Maine Potash Feldspar for Cornish Stone.—This gives a less vitrified slip, which is softer and more absorbent. With this combination of materials the potash feldspar gave less fluxing action than the Cornish stone or the Brandywine feldspar.

Substitution of American Ball Clays for English Ball Clay.—Kentucky Construction and Improvement Company's A and AA and Mandle No. 1 S. G. P. and No. 1 W. W. C., replacing English ball clay, gave whiter slips which are less vitreous and more absorbent. The Mandle No. 3 was more nearly a duplication of the English ball as it contained a high content of carbonaceous material and burned to a creamy color, similar to that produced by the English clay.

English ball clay seems to have a greater ability to cover a grogged surface without cracking than do the American ball

clays tested. The latter were tested in the slips singly and in various combinations. The English clay somehow gives a much smoother working action and even can be used as a slip alone with careful spraying. It produces an ink-proof surface at cone 6–7. However, the color is not white, but a light cream, so its use is restricted. A slip containing 100 per cent ball clay is dangerous with slight variations of thickness of spraying.

Substitution of English Ball for English China Clay.—The original slip contained 25 per cent English china clay and 10 per cent English ball clay. There was increasing cream color with higher ball clay content, slight increase in the number of cracks, and increase in vitrification.

From this series we found that at least 20 per cent English ball clay could be used in the above formula K with no marked change in color or increase in cracking. On the other hand, the increased ball clay did not decrease the cracking. Various slips containing 60 per cent English ball clay have given good result, save for the cream color.

Addition of White Lead.—White lead was added up to 12 per cent addition. Six to 12 per cent gave more glossy and less absorbent surfaces which had a tendency to blister. This was especially true with the highest contents of lead and in the presence of reducing gases. There was no apparent change when the lead content was under 6 per cent. At these temperatures a considerable quantity of lead was volatilized. The cracking was not diminished on poor surfaces, save where the blisters had obscured the cracks.

Addition of Ground Glass and Frits.—The obeject of these additions was to cause early fusion and greater strength at the low temperatures before the higher temperature fluxes gave action. Ground glass increases the gloss. This is especially noticed in slips where the content of glass varies from 10 to 20 per cent. The tendency to blister is marked in this same range. The opacity is diminished. The number of cracks is but slightly diminished unless there is a movement due to the development of gas vesicles, which occurs most easily with overburning or reduction.

Similar results were obtained with a frit of the composition:

$$\left.\begin{matrix} 0.20\ K_2O \\ .50\ Na_2O \\ .30\ CaO \end{matrix}\right\} \quad 0.40\ Al_2O_3 \quad \left\{\begin{matrix} 4.0\ SiO_2 \\ 1.0\ B_2O_3 \end{matrix}\right.$$

The blistering action is used at the present time to dull the surfaces of what would ordinarily be mat or semi-gloss glazes. The fused mass is full of minute blisters so that the reflection is broken up and the result, at a short distance, resembles the vitrified slip containing no frit. This method is principally used at lower temperatures for light cream or gray colors. Another method of dulling the surface is to introduce fine sand grains in an unground condition to the slip just before spraying.

The Introduction of Calcined Tennessee Ball Clay.—The object was to decrease the shrinkage of the slip and retard the development of cracks due to shrinkage. Clay was introduced in amounts up to 25 per cent. The ball clay was calcined to cone 6–7, ground wet in a ball mill to pass a 200-mesh sieve, dried and added to the mixture. The results were increased absorption, decreased shrinkage, increased number of cracks by weakening the slip, lighter colors, not over 10 per cent calcined Tennessee ball clay could be used.

Chlorite Mica.—Dana[1] classifies the chlorites as a group in the mica division. Normal formulas according to F. W. Clarke[2] are

$$4MgO.Al_2O_3.3SiO_2.3H_2O$$
$$12MgO.Al_2O_3.6SiO_2.9H_2O$$
$$2MgO.Al_2O_3.2SiO_2.3R_2O$$

"The minerals in this group are all silicates of alumina and magnesia (or iron) and contain about 12 per cent combined water. They are sometimes known as the 'hydro-micas.' In crystalline form they are very similar to the micas. However, they differ in being pliable, not elastic, softer and do not contain any large proportions of alkalies. The alumina content distinguishes them from talc and steatite."[3]

The analysis of "Canton A" chlorite, furnished by the American Mica Company, is as follows:

[1] "System of Mineralogy."
[2] "Data of Geo-Chemistry," U. S. Geol. Survey, *Bull.* **330**, p. 331.
[3] Miers, Henry A., "Mineralogy," MacMillan & Co.

SiO_2	37.40
Fe_2O_3	3.92
Al_2O_3	21.30
CaO	1.77
MgO	27.36
Ignition	8.20
	99.95

0.956 MgO	0.292 Al_2O_3	0.871 SiO_2
.044 CaO	.034 Fe_2O_3	.636 H_2O

A general formula combining the lime, iron and magnesia, gives

$$3.6MgO.Al_2O_3.3SiO_2.2.1H_2O$$

which is very similar to Clarke's first normal formula. Different samples have been found to vary considerably. The chief trouble is the iron content which easily becomes too high for use in light gray or white slips.

Ten to 15 per cent of the chlorite mica added to K slip decreased the absorption so that the slips were practically ink-proof, decreased the cracking to a minimum without blistering, and darkened the color. With some samples of chlorite, the color was a light brown; with better grades, a light gray which could be used for most work. Above 15 per cent chlorite, the slip becomes more absorbent and darker in color. The decrease in the number of cracks may be due to the additional fluxing action of this silicate of magnesia and alumina or the interlocking plate-like action of the fine mica-like grains.

Asbestos.—Asbestos belongs to the serpentine and talc division of minerals. Most of the asbestos comes from the Canadian province of Quebec. The range of eleven analyses of asbestos (chrysotile) from the principal deposits of Canada gave.[1]

SiO_2	39.05 to	42.64
MgO	40.07	42.97
FeO and Fe_2O_3	0.69	3.66
Al_2O_3	...	3.64
H_2O	13.47	14.50

The chlorite mica gave such an improvement in the elasticity of the slip that we thought we would still improve the fluxing

[1] Cirkel, Fritz, "Chrysotile-Asbestos," *Bull.* **69**, 1910, Can. Dept. Mines.

action by eliminating the alumina content (common to the chlorites) and increase the physical action from that of a plate to that of a fiber.

After the asbestos rock has been mined and crushed it is sorted into various grades depending principally on the length of the fiber. The longest fibers are used in the manufacture of cloth and the shorter fiber and "sand" for cruder ware such as asbestos board, insulation coverings, fire-proof cements and electrical apparatus. The long fibers demand the higher price but contain the lowest content of iron. Likewise the long white fibers are very bulky and when ground with a slip or glaze require far more water than the more impure and heavier grades.

For our experiment we used two grades—John-Manville 60, at twenty cents per pound in pound lots, and their 201 A at three dollars per pound in pound lots. The 60 is a darker fiber of shorter length than the 201 A and contains more iron. The latter is very similar to that used in the backing of gas grates.

Grinding for three hours in a ball mill reduces the fibers, not to impalpable matter, but to smaller threads, which are still long enough to exert a fibrous action and yet are mobile enough to be sucked out of a pint cup and sprayed onto a piece of terra cotta.

More water must be used for the bulky 201 A fiber to give it low enough viscosity for spraying. Where the ordinary slip can be sprayed with a specific gravity of 1.470, a 4.0 per cent 201 A asbestos slip must be brought down to a specific gravity of 1.260. Consequently, because of the greater amount of water, an apparently thicker coating must be sprayed on the ware. One and 2 per cent 201 A slips and the 60 slips are more nearly normal.

Slips containing asbestos fiber can be screened only with great difficulty. The fibers easily clog and mat on the sieve wires. A 10- or 12-mesh screen will be about the finest mesh possible for large quantities of slip. Freshly ground slip would cause but little trouble with the ordinary spray guns. After slip has been standing in tanks for some time there may be considerable number of dry particles to screen out.

Asbestos slip does not flow evenly like the ordinary slip, but hangs together in wet clusters. This same effect is noticed in

spraying. There is too much of a spotting action, resulting in an uneven surface. As this shrinks in drying and burning, it smoothes out to a considerable extent and the fibers are fused into the mass of slip.

Such a slip can be painted or piled onto a dry clay surface with a spatula and form a smoother surface than by spraying. Likewise it will stand far more abuse in regard to thick coatings than the ordinary slips which crack very easily.

While the shrinkage is greater, the ability to fill internal angles of ornament without cracking is greater. Asbestos threads are crystals and have smooth sides like threads of glass. Wool and cotton threads are rough and cohere more tenaciously. If the asbestos slip is left to itself in drying and burning and does not have a body to adhere to, it shrinks considerably. When spread out in a thin layer over a dry surface, the crystal threads can slide over each other and still hold the mass together. This cohesion is so strong that sometimes there is bridging of the internal angles in place of the usual cracking. For a body which ordinarily showed surface cracking 1.0 to 3.0 per cent 201 A asbestos gave excellent results. The impure 60 fiber gave improved results also with small amounts. In one case, by actual count, the number of minute cracks on tooled samples 7.5 by 10.5 inches was as follows:

Per cent, 60 asbestos.....	0.0	0.5	1.5	2.0	2.5	3.0	3.5	4.0
No. of cracks per sq. ft....	983	108	18	27	29	35	18	9

One hundred cracks of the sizes counted passes as a perfect surface.

One or two per cent asbestos carrying five per cent iron oxide adds only 0.05 to 0.10 per cent iron oxide to the slip so that the ware is given but a slight gray color.

The fluxing action of two or three per cent asbestos seemed as great as that of 10 to 15 per cent chlorite mica, and we found:

a. The effect per unit weight was greater than that of white lead or the frits used up to contents of 5.0 per cent.

b. There is a possible improvement in the color when the iron-free asbestos is used.

c. There is a possible decrease in crazing with the high flint slips.

Asbestos in Glaze Work.—Asbestos has been tried on large-sized samples in the underslip for glaze work, with a view of filling the internal angles without cracking. The indications were good. Blistering was encountered when the content of asbestos in the underslip reached 3.0 per cent. One per cent added to the underslip gave a noticeable improvement.

Three per cent asbestos 201 A was included in the following mat glaze:

Maine feldspar	16.4
Cornish stone	16.4
Brandywine spar	16.4
Flint	4.2
China clay	10.0
Ball clay	3.7
Whiting	9.1
Zinc oxide	8.5
Barium carbonate	7.0
Tin oxide	5.3
Asbestos 201A	3.0
	100.0

Although it showed a very rough surface when dry, it fused and smoothed out normally at cone 6 and filled the internal angles nicely without an underslip when sprayed on the bare body.

It must be remembered that while the mica and asbestos slips have given good results on full-sized pieces of terra cotta, the study has not progressed beyond the experimental stage. The physical difficulties encountered with asbestos slips are great and would be troublesome with the ordinary commercial practice. The present prices of the better grades are prohibitive and would prohibit use, save on a small scale, such as for painting for polychrome work, and so forth.

General Conclusions

The physical condition of the body upon which vitrified slips and glazes are sprayed is of fundamental importance in the production of perfect surfaces. The maximum size of grog grains and the proportioning of the grog sizes, the methods of pressing, finishing and spraying are all of utmost importance.

While the composition of the slip needs thorough investigation, we would suggest that the shape of the individual particles be also investigated for the production of unbroken coatings. This includes the study of the magnesia and magnesia-alumina silicates as represented by asbestos, steatite and the minerals of the general mica division.

THE USE OF AMERICAN RAW MATERIALS IN THE MANUFACTURE OF WHITE WARE POTTERY[1]

By A. V. Bleininger and W. W. McDanel

At one time during the war the curtailment of shipments of kaolin and ball clay from England was seriously considered by the War Industries Board. This at once brought up the question as to whether satisfactory white ware pottery could be manufactured from domestic clays, it being understood, of course, that American feldspar and flint are already being used. Upon discussing this matter with Mr. Marcus Aaron, president of the United States Potters' Association, in April, 1918, it was suggested that a test be conducted consisting in preparing a series of bodies and making them into pottery under commercial condi-

Table 1—Composition of Bodies

No.	Feld-spar	Flint	N. C. kaolin %	Del. kaolin %	No. 1 Ga. kaolin %	Washed S. C. kaolin %	Fla. kaolin %	Un-washed S. C. kaolin %	Ten-nessee ball clay %	Ken-tucky ball clay %
1	13	32	22.8	..	..	..	15.2	..	9	8
2	13	32	15.2	..	..	..	22.8	..	9	8
3	13	32	22.8	..	7.6	..	7.6	..	9	8
4	13	32	15.2	..	7.6	..	15.2	..	9	8
5	13	32	7.6	..	7.6	..	22.8	..	9	8
6	13	32	22.8	..	15.2	..	..	..	9	8
7	13	32	15.2	..	15.2	..	7.6	..	9	8
8	13	32	7.6	..	15.2	..	15.2	..	9	8
9	13	32	..	..	15.2	..	22.8	..	9	8
10	13	32	15.2	..	22.8	..	..	..	9	8
11	13	32	7.6	..	22.8	..	7.6	..	9	8
12	13	32	..	..	22.8	..	15.2	..	9	8
13	13	32	..	22.8	..	..	15.2	..	9	8
14	13	32	..	15.2	..	..	22.8	..	9	8
15	13	32	..	22.8	..	7.6	7.6	..	9	8
16	13	32	..	15.2	..	7.6	15.2	..	9	8
17	13	32	..	7.6	..	7.6	22.8	..	9	8
18	13	32	..	..	..	7.6	30.4	..	9	8
19	13	32	..	22.8	..	15.2	..	..	9	8

[1] By permission of the Director, Bureau of Standards.

TABLE 1—(*Continued*)

20	13	32	..	15.2	..	15.2	7.6	..	9	8
21	13	32	..	7.6	..	15.2	15.2	..	9	8
22	13	32	..	..	..	15.2	22.8	..	9	8
23	13	32	..	15.2	..	22.8	..	..	9	8
24	13	32	..	7.6	..	22.8	7.6	..	9	8
25	13	32	..	..	..	22.8	15.2	..	9	8
26	13	32	19.0	19.0	..	..	..	..	9	8
27	13	32	15.2	15.2	3.8	..	3.8	..	9	8
28	13	32	11.4	11.4	7.6	..	7.6	..	9	8
29	13	32	7.6	7.6	11.4	..	11.4	..	9	8
30	13	32	3.8	3.8	15.2	..	15.2	..	9	8
31	13	32	..	..	19.0	..	19.0	..	9	8
32	13	32	15.2	15.2	..	..	..	20.0	9	8
33	13	32	11.4	11.4	3.8	..	3.8	7.6	9	8
34	13	32	7.6	7.6	7.6	..	7.6	7.6	9	8
35	13	32	3.8	3.8	11.4	..	11.4	7.6	9	8
36	13	32	..	..	15.2	..	15.2	7.6	9	8
37	13	32	11.4	11.4	..	..	..	15.2	9	8
38	13	32	7.6	7.6	3.8	..	3.8	15.2	9	8
39	13	32	3.8	3.8	7.6	..	7.6	15.2	9	8
40	13	32	..	..	11.4	..	11.4	15.2	9	8
41	13	32	7.6	7.6	..	..	..	22.8	9	8
42	13	32	3.8	3.8	3.8	..	3.8	22.8	9	8
43	13	32	..	..	7.6	..	7.6	22.8	9	8
44	14	32	14.0	17.0	..	..	8.0	..	7.5	7.5
45	14	32	16.0	16.0	..	..	10.0	..	6.0	6.0
46	14	32	12.0	12.0	8.0	..	10.0	..	6.0	6.0

tions at a number of East Liverpool plants. Accordingly, a coöperative arrangement was perfected between the United States Potters' Association and the Bureau of Standards according to which the latter was to prepare a series of bodies and to supervise the making up of the same at East Liverpool. The Association was represented by a committee consisting of Messrs. Joshua Poole, *Chairman*, H. N. Parker, Patrick McNicol, C. L. Sebring and W. L. Smith, Jr.

Experimental

General Procedure.—The committee was fortunate in securing for this purpose the experimental plant of the Patterson Foundry and Machine Co., at East Liverpool, which was prepared by thoroughly cleaning the blunger, piping and filter press and putting the machinery in the best condition. The

junior writer was in charge of the preparation of the bodies, personally attending to the weighing and the other manipulations, in which he was assisted by a slip maker of the Homer-Laughlin China Co., very expert in his line of work.

Each batch of 150 pounds, after having been filter pressed, was carefully numbered, kept moist and taken to one of the potteries where it was made up into ware, dried and bisque-fired. Ten potteries coöperated in this work.

Each body was accompanied by a question sheet filled out at the pottery, requiring detailed information concerning the working quality of the body, its behavior in drying, drying shrinkage, firing shrinkage, color, defects, and so forth. From each composition two dozen 8-inch plates and two dozen cups and saucers were made. Each piece was stamped with the body number. The pieces were finished and dried as usual and placed in saggers as is customary for bisque firing to cone 8. Standard cones were placed in the saggers. The plates were placed in the third ring, midway; the cups in the first ring, midway, and the saucers in the first ring and in the first four saggers from the bottom.

All of the bisque-fired pieces from the different plants were then taken to one of the potteries selected for this purpose, glazed with a regular whiteware glaze and glost-fired in one kiln to cone 4. In this manner the conditions of glazing were kept uniform and comparable for all of the pieces.

The glazed ware was collected and taken in baskets to the office of the United States Potters' Association. Unfortunately, a number of the question sheets accompanying the sets were lost in transit so that the shop data concerning a number of the bodies are lacking. Four bodies, 39, 40, 41 and 42, were not delivered for inspection. Upon the completion of the work the sets were arranged according to the body numbers and inspected by the committee of the United States Potters' Association. The findings of this jury concerning the appearance and ring of the ware were accepted as conclusive and are given in table 3.

Samples of each body were forwarded to the Pittsburgh laboratory of the Bureau of Standards, where the content of water of plasticity, volume drying shrinkage, modulus of rupture, volume

fire shrinkage and porosity at cones 7, 8 and 9 were determined. Duplicate sets of butters were also jiggered at the laboratory in order to estimate the working quality of the bodies.

Clays Used.—The bodies were intended to show only the qualities of the different American primary and secondary kaolins. For this reason in 43 of the bodies the flint and feldspar were kept constant at 13 and 32 per cent, respectively, and the ball clays introduced as 9 per cent of Tennessee and 8 per cent of Kentucky ball clay. The variable factor then, is that relating to the 38 per cent of kaolin. No cobalt stain was used in any of the bodies, since color comparison would have been very difficult if this factor had been introduced. The general color of the body series, therefore, has a light cream tint, though some of the compositions compare very well with the regular pottery bodies to which cobalt has been added. The kaolins used were those from Florida, North Carolina, Georgia, Delaware and South Carolina, representing stock shipments, with the exception of the last named material, of which a special shipment was secured, consisting both of washed and unwashed clay. The materials were secured by the committee of the United States Potters' Association.

The compositions of the bodies are given in table 1. Constant feldspar, flint and ball clay contents are maintained in all but three compositions, 44, 45 and 46, which were suggested at a conference of potters held several years ago. In these series it was intended to cover the possible ranges of composition without including combinations which offer obvious practical difficulties.

For the purpose of estimating the amount of residue left by the different materials these were tested by passing them in the slip state through a 130 lawn with the following results:

Material	Per cent residue
South Carolina kaolin, raw	10.75
South Carolina kaolin, washed	1.50
North Carolina kaolin	2.00
Georgia kaolin	6.00
Florida kaolin	1.00
Flint	6.50
Feldspar	1.50

Owing to the comparatively small quantity of body, 150 pounds, it was not thought necessary to blunge the materials more than from three to six hours, varying with the composition. The amount of water required was gauged according to the consistency commonly employed. The experimental blunger rotated at a speed of 56 revolutions per minute. The pressure employed in filtering was adjusted to give cakes of the proper consistency.

The amount of knockings left on the 130 lawn was determined in each case with the following results. The residues are higher than those usually found in pottery practice, which may be attribued to the shorter time of blunging:

TABLE 2—AMOUNT OF RESIDUE FROM EACH BODY LEFT ON A 130 LAWN

Body number.....	1	2	3	4	5	6	7	8
Residue, %.....	5.5	...	..	..	..	..	..	8.23
Body number.....	9	10	11	12	13	14	15	16
Residue, %.....	9.62	11.2	7.4	..	5.71	4.45	4.95	4.9
Body number.....	17	18	19	20	21	22	23	24
Residue, %.....	5.25	3.51	5.73	2.82	1.93	3.13	3.49	2.34
Body number.....	25	26	27	28	29	30	31	32
Residue, %.....	5.95	2.09	4.96	6.11	6.97	9.55	6.99	8.73
Body number.....	33	34	35	36	37	38	39	40
Residue, %.....	8.76	4.77	5.78	6.6	4.39	5.99	5.72	7.40
Body number.....	41	42	43	44	45	46		
Residue, %.....	4.42	7.07	6.70	4.50	4.28	4.24		

The results of the work gathered from the returned question sheets, the results obtained at the Bureau of Standards laboratory, and the observations as regards the finished ware submitted by the committee, acting as the jury, are collected in table 3. For purposes of comparison two regular white ware bodies, V and P, from East Liverpool plants have been added.

Discussion of Results

Water of Plasticity.—The water content required by these bodies made from American materials does not average higher than that used in the regular bodies. There are exceptions, however, when larger quantities of Florida, Georgia and South Carolina clays are introduced with smaller proportions of North Carolina and Delaware kaolins. Thus the highest water content

obtained, 35 per cent, is obtained with 22.8 per cent of South Carolina and 15.2 per cent of Florida kaolins. The average water content of the bodies made from American materials is 31.3 per cent.

Drying Shrinkage.—The shrinkage upon drying was determined accurately for all of the bodies and expressed in terms of the dry volume. This was done as it affords the only method of obtaining the shrinkage values with the desired accuracy necessary for comparison. It is a well-known fact that linear shrinkage measurements are subject to considerable variation. As is to be expected, the drying shrinkage varies much like the water content, though not strictly parallel with it in every case. The average shrinkage does not differ materially from that of the two commercial bodies. There are, however, decided variations in the linear drying shrinkage of the bodies as taken from mold measurements which do not agree with the total shrinkage values as is to be expected, since the contraction is never uniform in all directions. In addition errors in measurement are apt to occur. The linear shrinkage measurements vary from 1.61 to 5.27 in terms of the wet length.

Behavior in Jiggering.—Nearly all the bodies behaved well in being made up into ware according to the shop reports. In a check series of jiggering trials made at the Bureau of Standards' laboratory only bodies 5, 44 and 46 were somewhat unsatisfactory.

Strength of Bodies in the Dried State.—Although it is generally assumed that the English ball clays are responsible for the plasticity and also the strength of white ware in the dried state, it was found in these tests that the use of American ball clays did not result in a lower average strength. In several cases the strength is greater than that of the usual commercial body.

The tests were made by pressing the body into bars, 7 inches long and 1 × 1 inch in cross section. After drying these were placed upon supporting rolls, 6 inches apart and a load applied at the center. The weight required to break the bars is used to compute the so-called modulus of rupture which indicates the transverse strength. It will be noted that moduli as high as

TABLE 3—RESULTS OF EXPERIMENTAL WORK

No. of body	Makers of ware	Water content of plastic body, % of dry wt.	Volume shrinkage, % of dry volume	Linear drying shrinkage of ware, % of wet length	Modulus of rupture of dried body, lbs. per sq. in.	Volume fire shrinkage, terms of dry volume, % at		
						cone 7	cone 8	cone 9
1	H.-L. C. Co.	33.30	22.50	3.12	...	18.05	19.75	22.10
2	H.-L. C. Co.	32.20	23.50	3.12	...	17.80	19.20	22.15
3	H.-L. C. Co.	29.75	18.40	3.12	...	16.8	20.75	24.95
4	H.-L. C. Co.	30.40	22.25	3.54	...	16.5	18.75	24.25
5	H.-L. C. Co.	33.45	25.10	2.64	...	18.1	19.4	24.20
6	H.-L. C. Co.	29.40	19.30	1.17	...	17.3	18.7	23.50
7	H.-L. C. Co.	30.40	19.90	1.77	311	17.05	19.15	19.75
8	.....	31.15	21.30	..	261	17.85	16.50	23.40
9	.....	33.30	24.20	..	296	18.15	20.25	22.20
10	.....	27.70	15.30	..	264	17.70	19.30	23.80
11	.....	31.70	23.20	..	319	17.25	19.25	22.50
12	.....	30.50	21.60	4.44	319	18.70	19.60	22.25
13	S. P. Co.	32.00	22.50	2.49	322	...	19.15	22.60
14	S. P. Co.	31.45	22.20	2.88	281	...	18.05	22.20
15	S. P. Co.	31.30	20.03	2.49	277	...	18.65	23.15
16	S. P. Cp.	30.50	20.06	2.49	316	...	18.10	21.35
17	K. T. & K. Co.	32.60	22.30	5.09	291	...	18.50	21.65
18	K. T. & K. Co.	33.20	24.00	5.27	341	...	20.1	21.70
19	K. T. & K. Co.	30.60	19.42	3.97	213	...	19.25	23.25
20	.....	30.40	21.06	..	...	...	17.30	20.00
21	.....	29.90	19.86	..	275	...	13.85	20.40
22	.....	33.85	27.30	..	296	...	18.50	21.9
23	.....	29.20	17.95	..	236	...	17.20	20.7
24	.....	32.15	23.70	..	281	...	17.85	21.7

25	.....	35.00	26.40	..	308	18.35	19.75	23.0
26	.....	31.95	21.50	..	262	16.05	18.20	22.2
27	C. C. T. P. Co.....	31.40	22.1	2.19	249	15.30	17.55	21.8
28	C. C. T. P. Co.....	30.55	21.55	2.19	264	15.10	17.50	21.1
29	C. C. T. P. Co.....	31.85	23.05	3.24	296	15.95	17.20	20.4
30	C. C. T. P. Co.....	32.75	24.70	3.54	322	16.20	18.15	20.9
31	.....	33.00	24.55	..	346	17.55	18.70	26.6
32	.....	30.25	18.65	..	254	15.95	20.80	20.8
33	.....	29.65	18.95	..	304	15.85	17.65	21.1
34	.....	31.50	21.95	..	287	15.90	17.40	22.1
35	E. M. K. C. Co.....	31.60	22.60	5.05	291	15.95	18.05	20.80
36	E. M. K. C. Co.....	31.78	22.55	4.56	323	17.35	18.25	20.75
37	E. M. K. C. Co.....	29.50	18.40	3.76	266	...	17.15	22.9
38	E. M. K. C. Co.....	31.45	18.4	3.87	321	...	17.0	20.0
39	.....	32.22	23.50	..	241	...	16.55	20.45
40	.....	33.85	26.55	..	303	...	13.75	20.00
41	.....	29.95	19.76	..	200	...	16.85	20.00
42	.....	31.45	21.8	..	224	...	16.75	20.15
43	D. E. M. P. Co.....	32.20	25.6	3.68	232	...	16.70	19.30
44	D. E. M. P. Co.....	31.00	21.88	3.30	259	...	16.10	20.40
45	D. E. M. P. Co.....	29.80	19.30	3.11	224	...	16.55	19.80
46	D. E. M. P. Co.....	30.15	20.90	1.61	225	...	15.80	19.25
V	.....	30.10	20.20	..	203	...	21.05	25.25
P	.....	31.55	22.20	..	278	...	22.00	24.55

TABLE 3—RESULTS OF EXPERIMENTAL WORK (*Continued*)

No. of body	Linear drying shrinkage, % of dry length	Behavior in jiggering	Drying behavior	Defects in bisque fire	Porosity at cones, % 7	8	9	General appearance of ware
1	7.63	Good	O. K.	None	22.9	19.5	14.00	Fine specks, color good, 2 pieces crazed
2	7.62	Good	O. K.	None	21.5	18.8	16.1	Fine specks, good body and color
3	7.62	Good	O. K.	None	21.4	18.3	14.1	Clean, good body and color
4	8.80	Good	O. K.	None	19.4	16.1	11.1	Fine specks but good body and color
5	7.40	Good	O. K.	None	21.2	18.5	14.9	Like 4
6	3.56	Short	O. K.	None	20.9	17.3	12.0	Good body and color
7	6.20	Good	O. K.	None	21.4	18.5	13.6	Clean body and good color
8	...	Good	...	.....	20.9	18.0	14.4	Clean body and good color; some crazing
9	...	Good	...	.....	20.9	19.6	15.7	Good color; some crazing
10	...	Good	...	.....	21.1	17.7	13.9	Fair color; sound body
11	...	Good	...	.....	21.6	18.9	15.4	Creamish color, sound body
12	8.79	Good	O. K.	None	20.9	18.1	15.3	Good color, warps a little, good ring
13	7.05	Good	O. K.	None	21.6	18.5	15.4	Fine color; some crazing
14	6.13	Good	O. K.	None	21.3	15.7	14.5	Fair color; some crazing
15	7.28	Good	O. K.	None	22.4	20.1	13.6	Excellent color, some crazing
16	8.27	Very good	O. K.	None	21.3	20.0	15.1	Not a very strong body; some crazing
17	9.63	Good	Fair	None	21.8	20.9	18.4	Good body and color
18	10.20	Good	O. K.	None	21.8	19.8	16.7	Excellent color, body fair
19	8.10	....	O. K.	1 pc. cracked	21.8	19.2	14.8	Fair color, good body, some crazing
20	...	....	...	.....	22.5	21.0	16.6	Fair color; not a strong body; crazed
21	...	....	...	.....	22.6	21.0	17.9	Good color; body below average; crazed
22	...	....	...	.....	20.8	18.3	14.7	Color below average; crazed
23	...	....	...	.....	22.5	20.7	17.1	Color good; body weak; crazed
24	...	....	...	.....	23.0	22.2	16.1	Good color; crazed

25	...	....	...	.....	22.2	20.4	16.5	Good color; not crazed
26	...	....	...	.....	22.7	20.3	16.5	Fair color; underfired; crazed
27	6.6	Fine	O. K.	None	22.3	20.8	15.8	Good color and texture; crazed
28	7.24	Fine	O. K.	None	22.4	21.0	15.5	Good color and body; crazed
29	7.69	Fine	O. K.	None	23.3	20.7	17.3	Fair color and fair body; crazed
30	8.26	Fine	O. K.	None	22.8	20.7	16.8	Good color and body; crazed
31	...	Good	...	.....	22.4	21.3	16.8	Good color but body too open; crazed
32	...	Good	...	.....	24.1	23.0	18.5	Good color; ring not good; crazed
33	...	Good	...	.....	23.3	21.0	16.4	Good color; ring fair; some crazing
34	...	Good	...	.....	22.9	21.0	16.5	Good color and ring; crazing
35	9.19	Good	O. K.	None	21.7	20.9	16.7	Good color, body very good; some crazing
36	9.27	Fair	O. K.	None	18.7	20.0	17.0	Excellent color; fine body
37	7.8	Fine	O. K.	None	22.7	21.8	17.4	Good color; excellent body; crazed
38	8.27	Fine	Sl. warp.	1 pc. cracked	23.2	22.2	18.1	Good color and body; some crazing
39	...	Good	...	.....	23.4	22.4	17.8	
40	...	Good	...	.....	23.3	21.4	18.2	
41	...	Good	...	.....	22.8	22.1	18.1	
42	...	Good	...	.....	22.9	22.2	18.6	
43	7.29	Good	O. K.	None	23.4	24.1	19.3	Good body and color
44	6.25	Fair	O. K.	None	23.1	22.1	16.15	Good color and body; crazed
45	5.95	Good	O. K.	None	23.3	22.1	17.0	Good color but body not matured; crazed
46	5.20	Short	O. K.	None	22.2	21.9	12.3	Fair color and body; crazed
V	...	Good	...	.....	18.1	15.8	10.3	
P	...	Good	...	.....	18.8	16.1	10.1	

341 pounds per square inch were obtained, the average of the series being 279 pounds against the values of 203 and 278 of the two East Liverpool bodies. It is apparent, therefore, that no loss in strength occurs due to the use of American clays.

It might be added that no drying defects occurred in the ware made or in the specimens made in the laboratory.

Fire Shrinkage.—The total burning shrinkages were determined in the laboratory and expressed in percentage contraction figured on the basis of the dried volume. Using a large test kiln of 1 cubic yard capacity, fired with natural gas, the bodies were fired to temperatures corresponding to cones 7, 8 and 9, the time taken for the burn being about the same as in the commercial bisque fire. The specimens were made in the form of briquettes, about $2 \times 1 \times 1$ inches. The volumes were determined in the dried state and after each firing.

Confining our attention to the temperatures of cones 8 and 9, it will be observed that the average shrinkages of the 46 American clay bodies are 17.8 and 21.7 per cent, respectively, as compared with 21.5 and 24.9 per cent, which are the values obtained for the two standard bodies employing English kaolin. It is evident, therefore, that the American kaolins and ball clays resist vitrification to this extent and would require a higher temperature of firing if the same fire contraction were to be required. At cone 9, however, it is evident that the fire shrinkage is progressing with very much greater rapidity. Thus body 31 shows an increase in volume shrinkage from 18.7 to 26.6 per cent between cones 8 and 9. Other bodies which show a volume fire shrinkage of 23 or more per cent at cone 9 are 3, 4, 5, 6, 8, 10, 15, 19 and 25.

Porosity.—The porosity of the fired bodies expresssed by values showing the percentage of voids or pore space in terms of the exterior volume of the piece is a still better criterion of the stage of vitrification than the shrinkage. It will be noted that the bodies, employing English clays, show a mean porosity of 15.9 per cent at cone 8 and 10.2 per cent at cone 9. These figures are useful for purposes of comparison, but it must be remembered that they represent the joint effect of English kaolin

and ball clays. Studying the porosity figures for cone 8 it will be seen that but two bodies show a porosity of 16 per cent, namely 4 and 14. It would seem from this that the Florida and Georgia kaolins promote vitrification decidedly, which, of course, is a well-known fact. Assuming arbitrarily that a porosity of 19 per cent is permissible for whiteware fired to cone 8 we would have the following bodies pass this requirement: 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13 and 14. These are all bodies containing not more than 22.8 per cent of primary, or non-plastic, kaolins, such as the North Carolina and Delaware, together with Georgia or Florida kaolin, or both. It was found also that these bodies, with the exception of 8, 9, 13 and 14, showed no evidence of crazing in the finished ware. Beyond body 14 the introduction of South Carolina kaolin makes the bodies more refractory. Beginning with body 26, the bodies continue to be porous owing to the introduction of too large an amount of both North Carolina and Delaware kaolin, the introduction of South Carolina kaolin, or to both causes simultaneously.

Referring now to the temperature of cone 9, we find the general average of porosity of the American clay bodies to be 16 per cent, compared with 10.2 per cent for the typical East Liverpool compositions. Only three bodies approach the latter porosity value, namely, 4, 6 and 46. Assuming an arbitrary porosity limit of 15 per cent, it will be noted that the first ten compositions contain 8 bodies corresponding to this degree of density, indicating in a general way that the remarks made concerning the cone 8 firing apply. But at the same time it is apparent that the bodies as a whole are more refractory than those commonly made with English china clay and ball clay, and that we cannot expect to reach greater density without employing more feldspar. It is to be expected, however, that with 14 or 15 per cent of this constituent bodies sufficiently close may be obtained, especially if the firing can be carried somewhat higher than cone 8.

Defects in the Bisque.—Practically no defects were noted as regards cracking or checking in the bisque fire.

Appearance of the Ware.—It was the judgment of the committee that most of the bodies showed a very good color and appeared

to have a sound ring. No crazing was observed on the ware at the time of the examination by the committee with the exception of body 24. However, a set of pieces for each of the bodies was forwarded to the Pittsburgh laboratory where it was found, after six months, that bodies 9, 13, 22, 23, 24, 26, 27, 28, 29, 30, 32, 33, 44, 45 and 46 had crazed. All of the pieces were likewise subjected to a treatment consisting in placing them in boiling water and cooling them rapidly. This was repeated ten times and caused a number of additional bodies to craze.

This is what should be expected from bodies as porous as some of these are. It is evident that this can be remedied by an increase in the amount of feldspar or in the temperature of the bisque fire, or both. The drop in porosity necessary to produce ware free from crazing is not great since even under these conditions some of the bodies did not show this defect. The compositions which were found to show no crazing were 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 17, 18, 25 and 36. It is interesting to note that a porosity of 20 per cent seems to be about the limit at which the whiteware glazes may hold upon the body without crazing, though necessarily the boundary is not sharply defined. If the bodies, causing crazing, had been fired to a higher temperature, say cone 9, no crazing would have been observed.

Conclusions.—The question as to whether white ware pottery of satisfactory quality can be made from American raw materials exclusively must be answered in the affirmative on the basis of the facts presented. It is necessary to realize, of course, the fact that both the American ball clays and kaolins are of a more refractory nature than the English materials, especially the ball clays. This would necessitate the use of a slightly modified body composition consisting in using either more of the ball clay, or increasing the feldspar content by from 1 to 2 per cent, or in raising the firing temperature from $^1/_2$ to 1 cone, or in a combination of any of these three changes. These modifications are by no means important and would entail no hardship to the manufacturer.

While the present work did not concern itself with the question of an adequate supply or the uniformity in quality of the domestic clays it will be necessary to discuss briefly the real situa-

tion. It is a well-known fact that the closest approach to English china clay is obtained with a mixture of primary kaolin, such as the North Carolin or Maryland kaolin, with a secondary one, of the type of the Georgia or Florida plastic kaolins. Such a combination presupposes, therefore, the existence of an adequate supply of the primary kaolins. It is in this respect that we are lacking. While some very fine kaolin is being obtained from the North Carolina districts the quantity being marketed is not adequate for the needs of the entire industry. A similar condition exists with reference to the Maryland and Delaware deposits. Even though the amount of primary kaolin used were cut down to the minimum, an adequate supply could not be obtained at the present time. As to the exclusive use of plastic kaolins this is much easier said than done, as all practical potters know, and cannot be considered a feasible proposition. This situation is complicated by the needs of the paper industry, the tonnage of which greatly exceeds that required in the manufacture of pottery. It is evident that competition for all suitable materials on the part of the paper industry is a factor to be reckoned with. The question of the cost of the domestic and imported kaolins, also, cannot be disregarded, though it is of secondary importance, compared with the fundamental question of actual clay resources.

We are hence compelled to arrive at the conclusion that while white ware pottery of good quality can be produced with the exclusive use of domestic kaolins, the output of our mines is not sufficient to justify the elimination of the English china clay, which is supplied in uniform quality and at a cost competing closely with that of the domestic product. On the other hand, every effort should be made to increase the production of our kaolin mines and to search for new deposits so that ultimately we may be entirely independent of other countries with references to such basic materials as primary kaolin.

Furthermore, it should be the aim of every potter to make use of domestic clays to the fullest possible extent so that the kaolin mining industry may find it profitable to enlarge and improve its operations. This policy is the only safe and wise one if we are not to be forever dependent upon foreign sources, which might

at some time fail us entirely through unforseen conditions, such as legislative action prohibiting the export of the materials, etc.

The sincere thanks of the writers are due to the committee of the United States Potters' Association for its whole-hearted coöperation. The chairman, Mr. Joshua Poole, spared no pains to assist in this work. We are also greatly indebted to the pottery firms for carrying on the tests so carefully and the Patterson Foundry and Machine Company of East Liverpool for its generous assistance and coöperation.

Bureau of Standards Laboratory
Pittsburgh, Pa.

CRAFTSMANSHIP EXHIBITED IN FINE CUT GLASS

By J. J. Vallely

The purpose of this article is to sketch briefly the evolution of a piece of fine cut glass and to bring home to those persons whose taste happily makes them our readers, an appreciation of the specific qualities that give to one product the commanding place in cultured esteem. "The story of glass" excites the imagination at every step, from its primitive beginning to the point where craftsmen leave the well-worn path of mediæval method and press forward into the broader highway of modern science.

The artistic position of good quality, cut glass, places it noticeably apart from the poorer grades. To be capable of judging glass is to add vastly to one's pleasure in owning and in giving. There are few gifts more acceptable than nice cut glass. It appeals to people in all walks of life and while it is popular it would be even more popular if the majority of people knew what cut class should be.

Cut glass being a hand product consists of: first, a pretty design (or pattern); second, workmanship in cutting the design; and, third, in finishing (or polishing). Skill, in cutting, means that the cuts should be true and sharp. All cuts crossing each other should be exactly the same in depth, and all the detail work carried out in the same exact manner. Finishing (or polishing) is the next important part, and all cuts should be polished to a sparkling brilliancy. The nicest piece of cutting can be easily spoiled by poor polishing. This is very often done in factories where they do not have the modern methods, or where quality is not considered, which, I regret to say, are quite common.

The methods of polishing glass have changed or advanced during the past twenty-five years. At one time it was not thought possible to produce a brilliant polish by the use of acids. A small factory near Boston, Massachusetts, proved that it was not only possible but very practicable. This factory demonstrated that

a very brilliant polish could be obtained and by this method the melted edges, produced by the fast revolving brush wheel, was done away with, and a better quality of cut glass produced. The acid finish at that time was called the "electric polish," and so cleverly did this company conceal the real method that it was years before it became known that acids were being used for polishing and not electricity. This process has done away with the greater part of wheel polishing.

About twenty years ago, the composition emery wheels for glass-cutting purposes were introduced. For several years they did not prove very successful, but later improvements have made them very popular as they are much superior to stone wheels for most lines of cutting.

As a piece of glass comes from the annealing oven, before it has received any decoration, it is known as a blank. In the early days of glass cutting all blanks were made plain. Today, to save work and cheapen production, figured blanks are often employed, that is to say, the design is pressed into the blank while the glass is in a plastic state. The result is that a great amount of poorly cut and finished cut glass is placed upon the market. It requires skill to cut a nice pattern on a plain blank but less skill is required to re-cut the pressed cuts on the figured blank. In fact, workmanship and quality on this line of pressed glass are forgotten and consequently a large amount of glass that is a discredit to the cutting industry finds its way onto the market.

When the glass is properly cut and polished on a plain blank, a refraction is produced, almost equal to that of a diamond. When the design has been pressed into the blank, the prismatic effect is practically neutralized, the color is clouded, the sparkle subdued. To detect the cut glass made from figured (or pressed) glass, simply run the fingers over the inside of the article where the cutting on the outside is deepest, and a slight swelling on the inside will be noticeable to the touch. However, this does not condemn all pressed cut ware if it is properly cut and polished.

A great many people, in buying cut glass, judge quality by the weight. I have seen people reject a first-class piece on account of its not being heavy, and select a very inferior piece that was of

greater weight. I am sure they would not follow this same practice in buying other lines of art ware. Of course, best quality cut glass is cut on lead glass, and lead glass is usually heavier than lime glass, but to select nice glassware one must look for a pretty design and good workmanship in the cutting and brilliancy rather than to try to judge by weight.

Another line of glassware that we find upon the market is known as semi-cut glass. This is sold in a great many stores and often is sold for real cut glass. This is a cheap line of pressed lime glass with a small amount of dull cutting inserted here and there. It makes a very poor substitute for nice glassware.

In conclusion, I will say that we find a very pretty line of light ware upon the market. This line includes engraved and cut floral designs, which are very pretty. This line, like all other lines of nice cut glassware, consists of pretty designs, good workmanship and finish.

THE SOLUBILITY OF BORIC ACID FRITS[1]

By George Blumenthal, Jr.

The extent to which boric acid frits for white ware glazes are soluble in water has been more or less a mooted question. Some have claimed that they are quite soluble while others have held to the contrary opinion. It was thought desirable, therefore, to determine the solubility of a number of commercial frits, representing both the sagger and the furnace methods of melting. Nine samples were obtained, which differed rather widely in appearance, some being glassy, others more of a stony character; some appeared to be quite homogeneous, others contained undissolved particles of flint or clay. The compositions of the frits were not known.

The specimens were ground, thoroughly mixed and sieved through 20- and 40-mesh sieves. The material used was that which had passed the 20 but was retained on the 40-mesh sieve. The surface exposed to the action of the water was, therefore, practically constant for each sample. The amount used in each case was five grams placed in a glass cylinder together with 350 cc. of distilled water. Blank runs were made with water alone. The glass cylinders were almost filled and placed on a shaking machine making about 17 revolutions per minute. The liquid and the samples were thus agitated gently for 24 hours. No allowance was made for variations in the room temperature, which could not be controlled, but which for a determination of this kind may be considered to be a negligible factor.

After three or four hours the water showed a more or less pronounced degree of turbidity, varying from a slight indication to a decidedly cloudy condition. This was evidently due to colloidal silicic acid which separated out.

After having been shaken for the required time the supernatant solution was carefully decanted off and filtered through hardened filter paper, which operation was repeated to insure practically com-

[1] By permission of the Director, Bureau of Standards.

TABLE SHOWING RESULTS OF SOLUBILITY DETERMINATIONS

No.	Kind of frit	Appearance of frit	Colloidal silicic acid, %	Portion of frit soluble in water, %	Appearance of solution after shaking
1	Frit kiln	Glassy and clean	2.2	0.3	Clear, little silicic acid
2	Sagger	Not thoroughly melted	5.1	1.7	Quite cloudy
3	Frit kiln	Glassy and well fused	2.5	0.2	Cloudy
4	Sagger	Poorly fused	27.2	24.6	Very cloudy; frit slaked
5	Sagger	Slightly opaque, clean	2.2	1.9	Quite clear
6	Sagger	Glassy, contains some undissolved flint	4.6	1.8	Cloudy
7	Sagger	Glassy and clean	2.2	1.1	Clear
8	Sagger	Well fused, hard, of smoky appearance	2.2	8.0	Clear
9	Frit kiln	Glassy, undissolved flint	2.2	0.5	Clear

plete separation of the colloidal material. From the clear filtrate 50 cc. was removed, evaporated to dryness and the residue weighed.

The precipitate of colloidal silicic acid was likewise dried at 110° C and weighed as was the undissolved frit. From the latter figures the amount of dissolved material was checked. The results are compiled in the accompanying table.

It appears from these figures that all frits are somewhat soluble in water, a fact apparently due to the insufficient amount of melting they have undergone. This seems to be verified by the fact that those which have been melted in the furnace and have undergone more complete fusion show much lower solubility, though it is realized that the composition of such frits is also different. On the other hand, it is evident that sagger frits can be made so as to be insoluble for all practical purposes. In general, the more soluble the frit the more silicic acid is separated out, though there are distinct exceptions as in the case of 8.

From the operating standpoint only one frit should be expected to give trouble, No. 4, which evidently was insufficiently fused, a fact already indicated by its slaking. Considered theoretically, no objection can be raised against the type of composition employed which in spite of the high content of boric acid tends to produce insoluble borosilicates of which "Pyrex" glass represents an ideal example.

Although a discussion of the practice of fritting is not pertinent to the subject here under discussion it would seem that the use of the melting furnace would be desirable even from the standpoint of solubility since it would tend to produce frits uniformly insoluble, to say nothing of the saving in cost.

Again, in reference, to the sagger practice it might be said that thorough grinding and mixing of the constituents is to be recommended, as this would obviously tend to produce a more homogeneous structure. It is evident that due to the comparatively low temperature reached and the consequent high viscosity of the mass only a limited dissolving action can take place so that considerable flint may remain unacted upon or insufficiently combined.

In conclusion, the writer desires to express his thanks to the pottery firms who have coöperated by furnishing samples of frit.

NOTE ON THE LOAD BEHAVIOR OF ALUMINOUS REFRACTORIES[1]

By A. V. Bleininger

During the war it was found necessary to find for a certain purpose refractories more heat resisting than the average fire brick and as permanent in volume, under furnace conditions, as possible. For this purpose several mixtures were prepared and subjected to the load and fusion tests. These were based on the use of predominating amounts of high grade, calcined Pennsylvania flint clay and of artificially prepared sillimanite, consisting of 71.6 per cent of North Carolina kaolin and 28.4 per cent of anhydrous alumina, the latter being, of course, replaceable by the purer grades of bauxite. The sillimanite mixture, after thorough grinding of the raw constituents, was fired to a temperature of cone 20.

The plastic constituent was the usual fire clay employed as bond clay in the manufacture of flint clay brick in Pennsylvania, admixed with an equal part of North Carolina kaolin, or kaolin alone. It was thought that in this way the heat-resisting power of the brick could be improved, since usually the bond clay is the weak link in refractories of this type.

The first of these mixtures was molded into standard size bricks by the soft-mud process and all the others by dry-pressing, employing a pressure of 5000 pounds per square inch. The firing of the bricks was carried either to cone 14 or 16.

In order to bring about exceedingly severe conditions the usual temperature of the load test was raised from 1350° to 1400° C, except for mixture 1, for which the temperature of 1350° was retained. The pressure maintained was 50 pounds per square inch. The contraction is expressed in per cent of the original length of the brick.

The fusion test was conducted in the usual manner, employing a pot furnace with natural gas as fuel and with compressed air

[1] By permission of the Director, Bureau of Standards.

at 40 pounds per square inch. The extreme temperature limit which could be reached was cone 35.

The results of this work are compiled in the following table:

	Composition.							
No.	Calc. flint clay %	Artificial sillimanite %	Plastic fire clay %	Kaolin %	Temp. of firing Cone	Firing shrinkage %	Contraction in load test at 1400° C %	Cone at softening point
1	75	..	12.5	12.5	14	1.06	2.40 (1350° C)	33
2*a*	80	..	10	10	14	0.47	2.80	33
2*b*	80	..	10	10	16	0.35	0.84	33
3	80	..	..	20	16	0.83	0.88	35
4	..	80	10	10	16	..	0.61	above 35
5	..	80	..	20	16	..	0.48	above 35

From these results it appears that refractories high in alumina can be produced which resist load conditions and are practically constant in volume. The main requisite is that the burning temperature be carried sufficiently high. This is shown quite strikingly by the mixture 2*a* and *b*, where the increase in the firing temperature from cone 14 to 16 reduced the contraction in the load test from 2.8 to 0.84 per cent.

With reference to the use of synthetic sillimanite it is obvious that the calcination temperature must be carried high enough so that the mixture is really transformed into the compound in question, a point readily determined by microscopic examination. The failure of certain bauxite refractories in use undoubtedly is due to the neglect to realize that practical permanence of volume at furnace heats cannot be reached unless both the calcination of the aluminous ore and the firing of the bricks are raised to the proper temperature. This point can be established with accuracy for every mixture by means well known to ceramists and may be lowered by the addition of small quantities of such fluxes as boric acid. It is likewise essential that the kaolin and alumina or bauxite be ground together intimately before calcination so that the close physical contact necessary for the formation of sillimanite may be brought about.

It should be realized also that the molding of the bricks by dry-pressing assists not only in lowering the shrinkage in burning but the deformation under load conditions as well.

Refractories higher in alumina, therefore, are not inherently deficient in ability to assist load conditions; but it is evident that deformation under pressure depends largely upon the previous thermal history of the specimen. If it has already been caused to contract by sufficiently high calcination and burning it will resist compression within the limits required by practice. Since the present work was carried only to an alumina content corresponding to that of sillimanite this conclusion cannot as yet be extended to mixtures still higher in alumina, owing to the fact that sillimanite and mixtures higher in silica might possibly possess greater rigidity at furnace temperatures than more aluminous combinations. It is believed that synthetic sillimanite produced by proper heat treatment can be developed to form a very useful type of refractory for severe heat conditions.

The writer desires to acknowledge his indebtedness to Mr. F. A. Kirkpatrick for his assistance in the preparation of the specimens.

PITTSBURGH LABORATORY,
BUREAU OF STANDARDS.

CERAMIC ABSTRACTS

General

A comparison of the heat insulating properties of some of the materials used in fire-resistive construction. W. A. HULL. Bureau of Standards, *Tech. Papers*, **130**, (1919).—This investigation was preliminary to the investigation of fire-resistive properties of full-sized building columns, and was made for the purpose of determining the heat insulating properties of materials commonly used as protective coatings for steel. It was found that in clay specimens the rate of heat progress was comparatively rapid in hard burned samples but slow in soft burned ones, the porosity and density being important factors. In concretes the principal variable is the aggregate, and but little difference is indicated as to the ability of concrete of various aggregates to protect reinforcing steel placed near the surface. Greater differences are shown as to the final temperature attained near the center of the specimens and in the strength left in the mass of concrete after the test. These indications are somewhat favorable to slag concrete and particularly so to limestone concrete. The showing of gravel concrete, on the other hand, is somewhat unfavorable in respect to temperature attained in the interior and distinctly so in respect to the strength of the concrete after testing, although these results are not conclusive at the present time. Gypsum specimens showed relatively slow temperature progress and also low strength after test.

H. G. SCHURECHT

Comments on the constitutional formula of kaolin and other silicates. R. WEGSCHEIDER. *Z. Elektrochem.*, **21**, 22, 352 (1919).—While the majority of chemists understand the complex silicates as salts of polysilicic acid, in which the silicon atoms are combined with each other through the oxygen, one occasionally sees formulas in literature in which a direct combination of the silicon atoms are given. Such are the cases with the formulas of Simmonds (*Chem. Zentr.*, **1904**, 1, 77) and of Pukall (*Ber. Deutsch. Chem. Ges.*, **43**, 2105 (1910)). These formulas were already criticized by Manchot (*Ber. Deutsch. Chem. Ges.* **43**, 2603 (1910)) upon good grounds. Manchot states that the combinations between the silicon atoms in silicon-oxygen combinations, takes place only in reducing conditions, while silicates are formed without reduction. In inorganic combinations between silicon atoms the products are unstable, especially those containing oxygen. Silicic ethane is strongly reducing and the silicic oxalic acids are very explosive. Formulas with direct combined silicon atoms would not explain the staple condition of kaolin. If one has direct combined silicon atoms in silicates one is forced to believe that the oxygen atoms are directly combined. It is known, how-

ever, that such combinations are unstaple also as hydrogen peroxide, organic peroxides, etc., which are strongly oxidizing liberating oxygen. Regarding, silicates as salts of polysilicic acid does not prevent one from regarding those containing aluminum as salts of aluminium silicic acid with oxygen combinations between Si and Al. H. G. SCHURECHT.

Ovens and kilns with a high thermal efficiency. A. BIGOT. *Trans. Cer. Soc.*, **18**, 276–318.—See abstract "Furnace for High Temperatures," this JOURNAL, **1**, 498. A. J. LAMBERT.

PATENTS

Water purification. W. O. SNELLING. U. S. 1,325,213, Dec. 16, 1919. The base-exchanging property of zeolites has been utilized in the softening of water. The inventor transformed ordinary Portland cement into artificial zeolites by hydration and subsequent treatment with solutions of alkali-metal compounds. The cement is hydrated by boiling in water and is then agglomerated by another portion of cement. The calcium content is then withdrawn, say by means of acid. The transformation into zeolite is completed by boiling in a sodium carbonate solution. The product is said to be an efficient water-softening agent and may be regenerated like ordinary zeolites by treatment with strong hot solution of sodium chloride.

Alumina process of recovering. C. G. MINER. U. S. 1,324,318, Dec. 9, 1919. Alumina, substantially uncontaminated by silica, is obtained from aluminous silicates, such as the potash-bearing feldspars, leucite, sericite, etc., by comminuting the silicate and sintering with an alkali metal carbonate, then digesting with caustic alkali to dissolve the alumina and thus precipitating the alumina by carbonating the solution at boiling temperature to avoid substantial precipitation of silica. G. E. MIDDLETON.

Geological

The Chinastone and fireclay leases, hundred of Dudley, Kangaroo Island. R. L. Jack. Dept. of Mines, South Australia. *Review of Mining Operations* for half-year ended June 30, 1917, No. **26**, 1917, p. 38.—The geology consists of sediments changed to phylites and micaceous schists and sandstone. These are cut by a pegmatite dike, the exact dimensions of which are unknown, but which appears from evidence shown by the workings to be at least 1000 feet long and 100 feet wide. Most of the work was done in search of gems, but upon the exhaustion of such minerals attention was directed to the china stone derived probably from the dike. High-grade fire brick was produced, and also a china stone, but owing to competition by imported materials the work was abandoned. Now, however, small amounts of chinastone are shipped at irregular times. The fire clay prospects are not in good condition and information concerning them is meager. The following analyses are given: Silica, SiO_2, 70.20, 66.10; Alumina, Al_2O_3, 18.90, 20.28; Ferric oxide, Fe_2O_3, 1.02, 0.84; Lime, CaO, 0.08, 0.12; Soda, Na_2O, 2.58, 2.58; Potash, K_2O, 5.74, 8.76; Water at 100° C, H_2O, 0.04, 0.20; Water over 100° C, H_2O, 0.63, 0.30. E. D. ELSTON

Refractories

Refractory and abrasive matter, a new called Corindite. A. BIGOT. Paris.—In 1914 a French engineer, N. Lecesne, took out a patent for a new process of fusing bauxite in a very economical manner. Bauxite is very abundant in France, being chiefly of the white and red variety.

	White bauxite	Red bauxite
Al_2O_3	59.2	60.10
H_2O	14.10	14.20
TiO_2	3.50	3.30
SiO_2	18.50	2.85
Fe_2O_3	4.70	21.55

The Lecesne process consists in heating in a cupalo furnace a mixture of bauxite and anthracite by blowing air into the lower part. Before introduction of the charge a fire is started in the bottom of the furnace. The bauxite is reduced, aluminum carbide is formed, which, in the presence of air, is transformed almost entirely into alumina. The heat developed by the reaction is such that the mass goes into fusion by successive layers, a special contrivance preventing the matter from adhering to the sides of the cupalo. The operation terminated, the mass is cooled by means of surplus air, and a vesicular fused block is found, in which an immense number of small crystals are disseminated in the mass. The products are crushed and freed from metallic particles by means of a magnet and have the following analyses:

	White bauxite	Red bauxite
Al_2O_3	68.80	69.25
TiO_2	3.85	3.70
SiO_2	21.40	3.00
Fe_2O_3	5.25	23.35
Carbon	0.60	0.50
Loss on ignition	.10	.15

The fused bauxite has been designated by the name "corindite" on account of the crystalline corundum. White bauxite is very refractory while red bauxite resembles emery and is a powerful abrasive. The fusion point of corindite is higher than 1950° C, being more refractory than the original bauxite. This is explained by the fact that iron oxide has almost entirely united to form the spinel Al_2O_3FeO. Corindite is bonded with finely ground refractory material as bauxite or kaolinitic clay. Brick are made either by hand or machine and are burned to 1350°–1400° C. Brick made in this way expand slightly at 1700°–1730° and above 1750° shrink slightly, having a shrinkage of 3 per cent at 1850°. The porosity depends on the manner of making and brick last much longer in practice than the unfused brick.

As an abrasive the red bauxite compares favorably with Naxos emery. The main difference between the two is that the Naxos emery contains lime which lowers the fusion point to 1600° while the red bauxite may be heated to 1700° without melting. Emery wheels can be burned to 1500° with red bauxite,

which is impossible with the Naxos emery. Red bauxite is not as effective an abrasive as the artificial corundum owing to the lower content of alumina (70 per cent) as compared with that of artificial corundum (90–92 per cent).

H. G. SCHURECHT

Magnesite as raw material. THOMAS CROOK. *Trans. Ceram. Soc.*, **18**, 67–145 (1919).—The siliceous magnesite of Baudissero in the Piedmont is reported to have been used quite successfully in porcelain manufacture previous to the beginning of the 19th century. This particular magnesite was at that time regarded as a high-class china clay (terra da porcellana) and was not known to contain any magnesia. The essential features of the manufacture of refractory magnesia is as follows: (1) The finished products, whether as sinter obtained by dead-burning the raw magnesite, or as bricks produced by a second or further burning of the pulverized compressed sinter, should consist essentially of crystalline magnesia. The Austrian practice aims at obtaining a sinter containing at least 83 per cent of magnesia. Lime, silica and alumina are regarded as undesirable ingredients and should not exceed 5 per cent, 6 per cent, and 2 per cent, respectively. Iron oxide is regarded as a desirable ingredient, but the amount of ferric oxide is not allowed to exceed 11 per cent or so of the sinter. (2) The dead-burning of the raw magnesite should be effective, since it is only the inert and comparatively dense, crystalline product (periclase), into which caustic magnesia becomes transformed by prolonged heating at temperatures upwards of 1400° C, that can be regarded as refractory. The kiln temperature required varies with, and must be adapted to, the nature of the raw material. The temperature required for the sintering of Styrian magnesite is said to range from 1400° C to 1600° C, the average being about 1500° C, while that required for Grecian magnesite is stated to be much higher. (3) The production of good magnesia bricks demands the use of pulverized sinter of good quality. The sizing of the grains, the nature and proportionate amount of the binder used where such is necessary, the pressure under which the bricks are moulded, the drying conditions, are controlable factors, and appear to be taken carefully into account in the Austro-Hungarian process of brick manufacture. The aim in this process seems to be to secure bricks the volume-shrinkage of which in the final burning operation does not exceed about 15 per cent, and the nature of which renders them immune from any considerable shrinkage under the furnace conditions for which it is designed to use them. The best way to classify magnesites is on the basis of texture and composition as follows: 1. Spathic breunnerite (*e. g.*, Styrian, Austrian); 2. Spathic magnesite (*e. g.*, Quebec, Washington, and Norwegian); 3. Compact magnesite (*e. g.*, Grecian, Californian, Italian, Indian (Salem) and Australian). Deposits of spathic magnesite or breunnerite usually contain much more impurity than those of compact magnesite. Breunnerite is usually coarse in texture, and characterized by a considerable precentage of ferrous carbonate isomorphously mixed with the magnesium carbonate. Spathic magnesite is usually less coarse in texture, and is almost free from admixture with ferrous carbonate. Spathic

magnesite and breunnerite generally occur in association with dolomite, and are, therefore, liable to contain much lime impurity. The admixture of this dolomite is less intimate in coarse-textured spathic breunnerites of Austria, than it is in the closer-textured spathic magnesite of Quebec. Partly for this reason, and partly owing to the isomorphously mixed ferrous carbonate, the dressing of breunnerite and elimination of the dolomitic impurity is economically more feasible than in the case of the purer spathic magnesite. Producers of the raw material seem to expect that the return of normal conditions will permit the Austrian exports to dominate the refractory magnesia market as in the past. One of the most important of the advantages that favor the Austrian export trade is the open-cast working of large deposits of breunnerite, the nature of which permits of the production of standard qualities of sinter at cheap rates. It would perhaps be unreasonable to expect that sintered magnesia should be produced at such a cheap rate under the less favorable mining conditions prevailing in Greece, Italy, India and California. Elaborate discussions of the mineralogical characteristics and geological occurrence of various magnesia minerals are given. A. J. LAMBERT

Some notes on silica and other refractory bricks made from non-plastic materials. G. W. MOTTRAM. *Trans. Ceram. Soc.*, **18**, 148–53 (1919).—The economical kiln is one of large capacity, running up to 100,000 bricks. Satisfactory results in making fire brick were obtained with 90 per cent grog and 10 per cent fire clay, when the raw clay was ground to a fine slip with two or three times its weight of grog and the resulting mixture afterwards mixed with the remainder of the ground grog. Bricks made on this principle from calcined Stourbridge fire clay showed no contraction after repeated burning, and after a week's exposure in the port of an open-hearth steel furnace came out with the edges quite sharp. Le Chatelier gives the results of tests of bricks made by a similar process in a French works. (1) With all fine material the crushing strength reached 4,540 pounds per square inch. (2) With coarse grains passing 100-mesh, and retained on 120-mesh, 993 pounds per square inch. (3) With fine + graded grains up to $^1/_2$ inch the average was 3,095 pounds per square inch. All these bricks were burned at 1300° C. The durability of bricks made on this system, in the same works, from similar material, and used under similar conditions, was some 200 to 300 per cent in excess of bricks made with the usual method of grinding. A. J. LAMBERT

Furnace for testing fire brick under load at high temperature. C. H. LOVEJOY. *Chem. Met. Eng.*, **22**, 109.—Description of a load test furnace for fire brick in use at the Pittsburgh Testing Laboratory, with plans for building furnace. The main difference between this furnace and type outlined by American Society for Testing Materials lies in the manner of applying load and the means of determining load during failure of brick under test. Pressure is applied by means of a spring, which carries brick to ultimate failure, determines variation in load sustained by brick at higher temperatures and gives rate of failure. A pressure of 50 pounds per square inch is

used, which is double that recommended by the A. S. T. M. The pressure is obtained through blocking, passing through bottom of furnace. The flame is led out through a chamber in back of furnace to prevent burning off of outlet pipe. Rate of heating is 500° C in first hour and up to 1350° C in five hours with this temperature maintained for one hour. Poor brick start to fail at as low as 950° C or 1000° C. Such brick show complete failure below 1200° C, the spring having returned to its original length with the load reduced to zero. Load remains constant in test and different rates of heating for different grades of brick are suggested. Fair brick will start to fail at about 1100° C and the spring will have about 25 pounds pressure per square inch left on them at 1350° C. First class brick will generally show no signs of failure before 1200° C, and many will stand 1300° C before starting to fail. Only two bricks were found which would show no sign of failure at 1350° C. All brick fail below 1500° C. R. R. DANIELSON

Refractory product problems. A. BIGOT. Paris.—Publication by the author. When refractories are heated to high temperatures there is a certain group which change in volume either shrinking as clay refractories or expanding like silica refractories, while another group show practically no volume change when heated to high temperatures. In the pamphlet products with a constant volume are discussed, these being divided into natural mineral refractories and artificial minerals. Under the group of refractories made from natural minerals we have (1) spinels, principally the iron chromium spinel, (2) natural corundum (emery), and (3) zircon.

Chromite, $FeOCr_2O_3$, comes chiefly from New Caledonia, Canada, Siberia, and Greece. Brick are burned to 1500° and show little shrinkage when burned to 1700°. The other spinels are the magnesium-alumina and the iron-titanium spinel which, however, are comparatively rare. Iron chrome brick are excellent refractories, being especially resistant to slag action.

Natural corundum consists of a mixture of alumina (95–98 per cent) with silica. It is obtained chiefly from Madagascar, India and South Africa. The brick are burned to 1400° and show little shrinkage when burned to 1700°. The softening temperature is not far below 2000°. Experience in using these brick in a Martin furnace revealed the fact that they were readily attacked by lime forming fusible aluminates and silico-aluminates.

Zircon from Madagascar contains about 33 per cent SiO_2 and 66 per cent ZrO_2 and 1 per cent impurities. To make brick 3–6 per cent kaolin or 3–4 per cent lime are used as a bond and the brick are burned to 1500°. When burned to 1750° they showed only a small shrinkage and the softening point is above 2000°. The presence of lime and iron oxide influence the softening point considerably. For instance, a mixture of 83 parts zircon, 5 parts lime and 12 parts iron oxide melts at 1830°. A mixture of kaolin (1800°) and zircon (2000°) may be obtained which softens at 1450°. In this manner it behaves similar to glucinum oxide which has a softening point of 2300° and a mixture of this oxide with kaolin melts at 1450°. Zirconia, ZrO_2 comes chiefly from Brazil. In purification it is treated with hydrochloric acid which

dissolves the iron and manganese. A product containing 98–99 per cent ZrO_2 may finally be obtained and this is calcined to a high temperature in an electric furnace before use. This material has a fusion point above 2000° and is used to make small special pieces as crucibles, tubes, and so forth.

Carborundum refractories (SiC) are good conductors of heat and are very resistant to sudden temperature changes. This material, however, is not very staple above 1500° when it decomposes(?). Fused quartz (1750°) is used chiefly for receivers, tubes, muffles, etc., and its use for other purposes is limited. Artificial corundum is prepared by melting bauxite in an electric furnace. It may also be prepared by the Lecesne and Gowen cupalo process.

Fused clay or kaolin may also be prepared by the cupalo process. This material is extremely compact and is obtained by heating sufficiently high enough to cause fusion. The density is increased about 20 per cent and the porosity decreased about 25 per cent. This material stands up about twice as long as that made in the oridinary way. Magnesite when treated by the Lecesne cupalo process is also extremely compact and shows little shrinkage when heated to 1700° C. The cupalo process is adapted for the calcining of quartz, dolomite and a number of other minerals. H. G. SCHURECHT

Study of silica products (Part II, bricks, etc.). A. BIGOT. *Trans. Ceram. Soc.*, **18,** 165–181. (Compare abstract "Silica Products," this JOURNAL, **1,** 582.)—Physical tests are carried out: (A) On products such as proceed from factories. (B) On the same products submitted to the temperature 1710° for an hour or two, or to 1650° for the time necessary for their complete expansion. *Density:* If the absolute density is not less than 2.45–2.50, it is certain that the burning has neither been high enough nor long enough; if this density is below 2.40 and tends to approach 2.35, then the burning can be considered satisfactory. Silica products based on compact flint present smaller absolute density, which should approach 2.25 and tend toward 2.22. *Porosity:* Varies from 8 to 20 per cent. The porosity should decrease when the products are heated to 1710°. *Resistance to crushing at ordinary and high temperatures:* Tests after heating at 1710° are made on whole bricks. After this burning, if softened or deformed, or melted, the brick are of inferior quality. Where they have resisted, three principal cases occur: (1) As the temperature is raised, the silicious grains increase in volume and porosity; the cement which surrounds them is partially vitrified, contracts and resists (without cracking) the expansion of the silica grains. The porosity of these products decreases in proportion as they are taken to higher temperatures, and the best silica products present this peculiarity. (2) Porosity has increased and the products are cracked and friable; the large grains of rock have expanded too much and have broken the cement. (3) Porosity after heating to 1710° has slightly increased, resistance to crushing at ordinary temperatures has perceptibly decreased, and resistance to crushing at 1500° has become zero. These grains of silicious rock have become friable, the chief material employed being such as falls into powder at 1710°; the cement which enwraps them has preserved its consistency and has not

cracked. This maintains in the product a certain resistance to crushing at ordinary temperature; but at 1500° the cement softens and, the grains no longer having any cohesion, the products are crushed under an insignificant pressure. A Fremont machine, modified by Bodin, is used for measuring crushing strength at all temperatures up to 1500° C. Refractory products fall in two classes: (1) Those of which the crushing resistance presents a maximum at about 1000°. (2) Those which do not present a maximum. In the first category must be ranged kaolins, clays, bauxites, silica products, products with carborundum as a basis, etc. In the second category should be placed products of chromite, Euboean or Styrian magnesia and so forth. In the first class until the culminating point is a little exceeded the material is crushed and ground to bits; in the descending part of the curve the material is flattened and behaves partly or wholly like a plastic substance. *Burning of the products:* 1600° C should be approached as near as possible. At this temperature a few hours' firing suffices to obtain a good result. This temperature can be reached in car tunnel kilns of Bigot's design. *Silica bricks which have been in Martin furnaces:* Bricks show three very distinct zones, D, E and F. The upper zone, D, is constituted by the unattacked silica brick. The intermediate zone, E, is brown; it includes, disseminated in its mass, white silica grains, analogous to those of the part D, and of which the size decreased in proportion as the lower part, F, is approached. These white grains are attacked by degrees by the brown matter which surround them; this attack is produced at their external surfaces, but, if they are attacked, the brown material penetrates to the interior of the cracks and the attack becomes more rapid. The lower zone, F, is grey; it no longer contains white silica grains, visible to the naked eye. The lower surface of this grey part, in direct contact with the furnace atmosphere, is brilliant and covered with a kind of brown glaze; it is hollowed in time by partial fusions which were produced there by contact of the dust and slags of the furnace. Bricks proceeding from basic or acid furnaces have analogous compositions and physical properties. The means of two series of analyses are:

	Silica	Lime	Magnesia	Iron oxide	Alumina	Manganese oxide
Grey part....	84.60	3.55	1.05	9.25	0.60	0.95
Brown part..	78.45	4.95	1.15	13.10	1.20	1.15

Cones of D and F and decimal standard 173 (1730° C) were bent in the same manner, though cone E, formed of brown material, melted like glass and was completely absorbed by its refractory support. The brown material E did not pass through the pasty condition like the materials D and F, but melted and liquified abruptly. The foreign matters, proceeding from the slags or the dust of the furnace, simply choke up the pores in the expanded parts of the bricks where they penetrate by capillarity, forming the brown material. Chemical action of the foreign materials begin as soon as impregnation is established. Examined under the microscope, the grey and brown parts present a complete transformation of the silica into cristobalite and tridymite. At 1500° C the grey part, F, resists a load of 138 kilog. per sq. cm. This is superior to that of all other refractories known. A. J. LAMBERT

Refractory materials of South Wales, notes on the. J. ALLEN HOWE. *Trans. Ceram. Soc.*, **18**, 27–42 (1919).—The refractory raw materials of South Wales, silica rocks, fire clays and dolomitic limestones are practically all obtained from the carboniferous strata. Up to the present time the silica rocks are the most extensively exploited. The first Dinas brick in the world were made in South Wales almost 100 years ago. The name "Dinas" is derived from a rocky eminence, the *Craig-y-dinas*, situated not far from Hirwaun, South Wales. The principal source of material is the Basal Grit layer of the Millstone Grit formation. The type of rock most in favor is a hard, compact, fine-grained quartzite with a buff, purple or blue tinge of color. This fine-grained stone may pass into one of more friable nature or into one containing pebbles of quartz. In some cases a hard form of pebbly quartzite is rejected; in others it is used along with the finer kind for silica brick. A certain amount of the incoherent grit may also be employed for the same purpose or for furnace sand. The rocks employed for silica brick are fairly uniform in their microscopic characters. They consist essentially of angular and subangular grains with silica cementation. The grains in most samples average 0.1 to 0.2 mm. diameter, but in others they are slightly larger with occasional small pebbles of quartz and chert. A small amount of mica is present in most samples and in some very little feldspar is observable; a little iron stain may exist between the grains of quartz and argillaceous matter in small amounts is sometimes present. Analyses of typical rock gives: 97.5–98.15 SiO_2; 0.40–0.70 Al_2O_3; 0.40 Fe_2O_3; 0.30–0.40 TiO_2; 0.20–0.30 alkalies and less than 0.10 each of other impurities. Various grades of fire clay and dolomitic limestone are found in the district.

A. J. LAMBERT.

Swansea district, science in relation to the industries of the. COSMO JOHNS. *Trans. Ceram. Soc.*, **18**, 1–14 (1919).—This article deals with the metallurgical and correlated metallurgical refractories industries in the district centering around Swansea, Wales. Among important natural resources are: abundant supplies of coals ranging from long-flame bituminous to extremely pure anthracite; slightly calcareous sands, suitable for hearths of copper refining furnaces; refractory sand for the manufacture of Dinas brick; and pure limestone for metallurgical uses. The manufacture of Dinas brick is the principal ceramic industry. Fire clays of high grade may exist but up to the present have not been discovered in the district. The need of a research institution in the district is emphasized. A. J. LAMBERT.

The corrosive action of flue dust on firebricks. J. W. MELLOR AND W. EMERY. *Trans. Ceram. Soc.*, **18** (1919).—This paper records the results of experiments consisting of mixing various kinds of flue dust and salts with a flame impinging on various types of fire brick. In general, the penetration by dusts is greater in fire clay than in silica fire bricks. In most cases the bond is attacked first and the coarser grains last. In silica bricks the depth of penetration by the dust is generally less the finer the grain. In the fine-grained bricks the coarser grains and the bond are both attacked, while in the coarse-

grained bricks the bond is alone attacked to any serious extent. It, therefore, follows that the bond of a silica fire brick offers the feeblest resistance to the attack of a corrosive slag. The attack on the coarser grains of silica fire brick varies with the nature of these grains. When there is much cementing material between the quartz grains the penetration of the rock fragments by the dust is greater than in the case of a compact rock made up of interlocking grains. Under oxidizing conditions iron oxide does not corrode silica bricks to any noteworthy extent, but under reducing conditions ferrous silicate forms and acts as a corrosive flux. In the trials with "bull dog" the silica bricks are far less attacked than fire-clay bricks; and generally the iron oxides corrode fire-clay bricks more than they do the silica bricks. The dusts apparently exert an influnece on the conversion of the quartz into the low specific grayity form or forms even where the coarse grains have apparently not been penetrated. When the dust is such that it can form a surface glaze the brick is protected from further attack, or rather the subsequent rate of attack is considerably diminished. This corresponds with a well-known practice of smearing a glaze mixture on the face of the brick work in certain kilns. If the surface glaze be fluid enough and in such a position that it can flow to a lower level these remarks do not apply, for the brick is rapidly eaten away as soon as the glaze begins to drip. The attempts to give the brick a resistant face by fusing the surface by means of a blowpipe flame are not satisfactory because the surface skin peels off. A. J. LAMBERT.

The standardization of tests for refractory materials. II. *Trans. Ceram. Soc.*, Report of Special Committee, pp. 251–263.—The use of standard lawns established by the Institute of Mining and Metallurgy are recommended. For elutriation separations a modified Schöne apparatus is specified. The results are reported in terms of surface factors. Preliminary specifications are given for a test of the corrosive action of flue dust on refractories.

A. J. LAMBERT.

Zirconia: Its occurrence and application. H. C. MEYER. *Trans. Ceram. Soc.*, **18**, pp. 264–275.—See abstract "Zirconia," *J. Am. Ceram. Soc.*, **1**, 838.

A. J. LAMBERT.

PATENTS

Refractory composition. E. T. FERNGREN. U. S. 1,324,546, Dec. 9, 1919. For crucibles and glass pots a composition is used comprising equal parts of calcined zirconium oxide, calcined or fused magnesite and a calcined high-grade alumina clay, the whole bonded with about 20 per cent German pot clay. If a more refractory composition is desired, the zirconium oxide is increased, while for furnace linings not in contact with molten material as low as 15 per cent raw zirconium oxide may be used. A poreclain body to which is added 15 per cent raw zirconium oxide and 7 per cent calcined magnesite is tough, elastic, non-conductive of electricity and not liable to cracking when subjected to sudden temperature changes. The zirconia, magnesia, alumina, and bonding clay may be fused, granulated and then bonded with a plastic clay. G. E. MIDDLETON.

Glass

PATENTS

Glass-drawing bait. H. F. CLARK. U. S. 1,324,229, Dec. 9, 1919. The inner surface of this bait is provided with a plurality of grooves, so arranged that the glass held thereby cannot loosen. The objectionable air leakage at this point is thereby avoided and the danger of breakage in taking down the drawn cylinder is reduced.

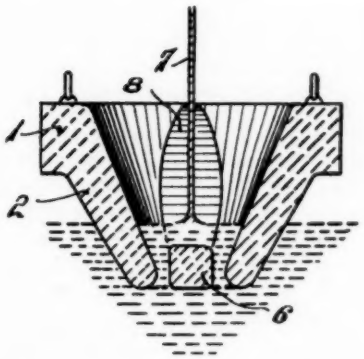
Glass, reinforced—and method of making it. C. AND V. SHUMAN. U. S. 1,324,361, Dec. 9, 1919. A sheet of celluloid is placed between two sheets of glass and the whole subjected to pressure at a temperature high enough to soften the celluloid and cause it to unite firmly to the glass sheets. The operation is carried out under reduced atmospheric pressure for the purpose of removing the air from between the glass and celluloid.

Glass, method and machine for gathering. K. E. PEILER. U. S. 1,324,464, Dec. 9, 1919. The gathering head is thrust into the fluid glass in the melting furnace and rotated so as to gather a mass of glass simulating hand gathering. It is then withdrawn from the furnace to an auxiliary hot chamber, wherein the glass accumulated on the head is allowed to slump or shed down from the head, in the heat of the chamber so that the desired quantity for a mold charge can be separated by gravity, aided by shears when necessary, and discharged while it remains in the most suitable condition for further manipulation.

Glass-furnace, apartment tank. W. M. MATHEWS. U. S. 1,324,917, Dec. 16, 1919. This is a regenerative, muffle furnace for making flint glass, those kinds of glass which contain large proportions of lead oxide and which cannot successfully be made in open pots. There are three longitudinally adjacent tanks, heated from above through thin muffle arches. Each may be drained into an adjacent refining chamber and each serves in turn as a melting, plaining and flowing tank.

Glass-furnace, regenerative. W. N. MATHEWS. U. S. 1,324,918, Dec. 16, 1919. There are two longitudinally adjacent muffle refining chambers which communicate at one end with a single melting chamber and at the other with a single cooling chamber.

Glass-drawing apparatus. H. K. HITCHCOCK. U. S. 1,324,965, Dec. 16, 1919. A refractory drawing basin 2 is immersed in the molten glass and terminates in a drawing slot. This slot is partly closed by means of a longitudinal refractory bar 6, which protects the glass in the basin and the sheet being drawn from the radiant heat of the mass of molten glass. For this reason the main body of the glass may be maintained at a higher temperature than would otherwise be feasible with consequent reduction of string, stone and rheam. The greater viscosity of the glass immediately above the



bar 6 operates to keep the sheet being drawn at the center line of the basin.

Furnace, glass tank. L. T. SHERWOOD. U. S. 1,325,172, Dec. 16, 1919. Water boxes are maintained in close contact with the outer surfaces of glass tank walls at the glass level. The walls thus cooled do not disintegrate so rapidly as they otherwise would.

Glass cane and glass tubing, apparatus for drawing. C. H. QUACKENBUSH AND J. C. SMEDLEY. U. S. 1,325,265, Dec. 16, 1919. An improved cooling chamber surrounds the tube being drawn, extending from the working level a considerable distance along the tube. As the tube is drawn from the working level of the glass in the pot falls, the cooling chamber automatically descends with it.

Glass-blank forming machine. J. RAU. U. S. 1,325,331, Dec. 16, 1919. A single valve mechanism controls the various parts of the machine in operation at the same time locking and unlocking the table on which the molds are mounted. It automatically opens the operating compressed air ports.

Glass shaping and blowing machine. A. WILZIN. U. S. 1,325,388, Dec. 16, 1919. This is a glass blowing machine in which the glass is introduced into the parison mold from above. The subsequent operation of molding stretching and blowing the parison, and of cooling and ejecting the finished bottle are performed automatically.

Glassware-transferring machine. J. P. MINGLE. U. S. 1,325,527, Dec. 23, 1919. This is a machine designed for handling glass fruit jars produced by that kind of machine which delivers the jars in an inclined or horizontal position, this machine operating to feed these jars to an off-bearing belt in an upright position.

Glass letters, apparatus for forming. E. C. GMELIN. U. S. 1,325,785, Dec. 23, 1919. A flat metal plate having the form of desired letter depressed therein constitutes the main member of the mold. This plate is supported

so that flames circulate beneath it and heat it uniformly. A sheet of glass is placed upon it and heated. As the glass is heated it softens and tends to fill the cavities which define the letter. At this stage a male die member is utilized to press the glass to the bottom of these molds.

Lamp manufacture. W. L. VAN KEUREN. U. S. 1,326,121, Dec. 23, 1919. This is an improvement in the sealing-in operation. The stem with its flare is placed within the neck of the lamp in the usual position. The lamp is rotated, its neck heated and the elongation and contact with the flare effected by means of a gravity-actuated pull-down fork. By this means the glass in the neck is thinned out uniformly. During this operation a pin on the stem support keeps the exhaust hole in the flare open. G. E. MIDDLETON.

White Ware and Porcelain

Apparatus for the charging and drawing of potters' ovens. M. P. FERNEYHOUGH. *Trans. Ceram. Soc.*, **18**, 154–164 (1919).—The apparatus (Eng. Pat. 13,387, 1915), falls essentially into the following parts: A gantry of hoist, detachable transport arms or stages, and the outer standards. Saggars which are conveyed on trucks can be run to the oven mouth, raised by the lift and transported to the desired place in the oven. In like manner trucks convey loaded saggars when fired, across the arms, when they are lowered and run into the saggar-house. The hoist, which is built up of steel bars, of angle and other sections, is telescopic and adapted to be brought into a small compass. The sides are detachable. This will permit the hoist to be readily brought within the oven, or withdrawn as the case may be. The transport arms or stages are telescopic. There will be occasions when a short arm only will be required, *e. g.*, at the commencement of the drawing, and at the conclusion of the placing. As the top saggars are removed it will be necessary for the man to work towards the rear of the oven, in which case the arm can be lengthened, so as to save time and labor. The outer standards can be used either extended or when closed. For the drawing of the oven their use is optional. They will not be required except perhaps at the end, but during the placing operations it will be necessary to bring them into service extended to their full length all the time. A. J. LAMBERT.

PATENTS

Base for supporting molded plastic articles. D. H. APPLEGATE, JR. U. S. 1,324,535, Dec. 9, 1919. Molded clay products such as bath tubs, glass pots, and so forth, are formed and dried on a sectional base, the sections being free to move as the article shrinks. Cracking is thus minimized.

Colloidal and finely subdivided substances, process of treating. B. SCHWERIN. U. S. 1,326,106, Dec. 23, 1919. The adsorbed components of colloidal, soluble or finely divided matter are separated from the adsorbing components by subjecting the colloidal matter, dispersed in a suitable medium, to electro-osmosis where by the adsorbed and adsorbing components separate and migrate through porous diaphragms of selected materials having a central anode and an outer concentric cathode. Clay may be cleansed of ad-

sorbed colloidal iron hydroxide by this method. U. S. 1,326,104 and U. S. 1,326,105 also relate to the treatment of colloids by electro-osmosis.

Clay, treatment of. W. FELDENHEIMER. U. S. 1,324,958, Dec. 16, 1919. This is a process of removing impurities from clays, such, for example, as fine quartz and micas from china clays, by suspension and sedimentation. In working with Fraddan clay a 5 per cent suspension is made and deflocculated by a sodium carbonate solution (1.5 per cent sodium carbonate based on the clay present). The supernatant suspension is allowed to remain in the settling tank not more than four hours. It is then decanted into a second tank and flocculated by an aluminum sulphate solution (1.5 per cent aluminum based on the clay present). The flocculating solution is added slowly. The suspension is allowed to remain in the second tank about four days or as many days as the hours required for deflocculation. Tannic acid may be employed as a deflocculator followed by H_2SO_4 as a flocculator. G. E. MIDDLETON.

Cement and Lime

Portland cement, the solubility of, its relation to theories of hydration. J. C. WITT AND F. D. REYES. *Concrete* (C. M. S.), **16**, 13 (1920).—It is common experience that water in which cement test pieces are stored soon contains substances in solution. It becomes soapy to the touch and has an alkaline reaction. Tests will reveal the presence of $Ca(OH)_2$, $Al(OH)_3$, sulphates, silicates of lime and alumina, and other compounds. The experimental work reported in this paper was very carefully and accurately carried out. Commercial cements were shaken with water for various lengths of time, and the amount of elemental Ca present in the water determined:

TABLE 1.—ANALYSES OF CEMENTS

	A	B	C	D
Loss on ignition	2.43	2.15	2.17	3.24
SiO_2	22.60	21.40	21.26	20.62
Al_2O_3	7.72	7.58	8.54	6.62
Fe_2O_3	1.76	1.70	2.08	2.56
CaO	61.32	62.94	62.82	63.50
MgO	1.08	1.37	1.13	1.43
SO_3	1.45	1.61	1.02	0.82
$K_2O + Na_2O$	1.63	1.14	1.17	1.33

TABLE 2.—FIRST SERIES. CALCIUM DISSOLVED FROM ORIGINAL CEMENTS DURING SHAKING WITH CARBON DIOXIDE-FREE WATER.

	A %	B %	C %	D %
Total calcium (Ca) present per gram of cement	0.4383	0.4499	0.4490	0.4539
First period, 20 hours	.0665	.0808	.0843	.0681
Second period 16 hours	.0071	.0125	.0089	.0259
Total for 426 hours	.1644	.1741	.1729	.1594
Total calcium dissolved (per cent)	37.51	38.69	38.50	35.12

A second series was run using those portions of the cements which had been air-separated by a Goreham fluorometer using an air pressure corresponding to 20 millimeters of mercury. No attempt was made to measure the size of grain. The analyses of the separated portions and the results obtained are shown in tables 3 and 4.

TABLE 3.—ANALYSES OF CEMENTS AFTER AIR SEPARATION

	A	B	C	D
Loss on ignition	3.91	3.73	3.55	5.00
SiO_2	20.48	20.22	18.96	18.40
Al_2O_3	7.81	7.17	9.58	8.95
Fe_2O_3	2.37	2.11	2.32	2.03
CaO	61.14	62.38	61.84	62.20
MgO	1.22	1.30	1.42	1.34
$Na_2O + K_2O$	1.07	0.64	0.63	0.87
SO_3	1.97	2.43	1.62	1.27

TABLE 4.—SECOND SERIES. CALCIUM DISSOLVED FROM FINE CEMENT BY SHAKING WITH CARBON DIOXIDE-FREE WATER

	A	B	C	D
Total calcium (Ca) present per gram of cement	0.4369	0.4458	0.4419	0.4445
Ca dissolved per gram of cement:				
First period, 1 day	.1282	.1432	.1519	.1535
Second period, 1 day	.0072	.0147	.0091	.0113
Total, 15 days	.1664	.1805	.1749	.1759
Percentage of total calcium that goes into solution	38.09	40.49	39.58	39.57

The main difference between this series and the first is the much greater amount of calcium going into solution during the first period—about double. The time necessary for completion was much shorter and the percentage of the total calcium present was higher. The total amounts of the other elements in solution are negligible in comparison with the calcium.

There is no important increase in the amounts of these constituents in solution after the first period of shaking. By using a sufficiently large volume of water per gram of cement, from 87 per cent to 92 per cent of the calcium in a cement was found to go into solution in 24 hours. The bearing of this work on the theories of hydration of cement is discussed in connection with the work of Richardson, Michaelis, Rankin, Klein and Phillips, and others. The following summary is given: The factors that affect the results are (*a*) absence of CO_2; (*b*) method of agitation; (*c*) fineness of grain; (*d*) volume of water; (*e*) time. Volume of water is the most important. The effect of temperature has not been studied. As the volume of water is increased, the amount of calcium going into solution in a given time increases rapidly. When cement is treated with approximately 8000 times its weight of water, 90 per cent of the calcium present goes into solution in 24 hours, with indications that still more would dissolve in a greater volume. Though the work

was not undertaken as a study of hydration, the results obtained are closely related to the theories of hydration that have been formulated from time to time. Since all the important compounds in cement contain calcium, and 90 per cent of the calcium present goes into solution, it may be stated that under favorable conditions the hydration of all important compounds results in the formation of $Ca(OH)_2$. It has not been found possible to obtain a saturated solution of $Ca(OH)_2$ by shaking cement in water. The presence of dissolved $Ca(OH)_2$ may inhibit further hydration, or it may be that when the concentration of the $Ca(OH)_2$ solution reaches a certain value, a colloid is formed according to the theory of Michaelis. F. A. KIRKPATRICK.

Plaster, the setting of. C. H. DESCH. *Trans. Ceram. Soc.*, **18**, 15–22 (1919). —Le Chatelier's account of the setting process is accepted. On mixing the burnt plaster with water each particle soon becomes surrounded by a layer of a solution which is saturated with regard to the hemihydrate, but strongly supersaturated with regard to the stable gypsum. Crystallization of gypsum soon begins, either spontaneously or more probably from nuclei which have persisted unchanged throughout the burning process. Growth of the crystals taking place from many neighboring centers, radiating groups are formed, and the interlocking of these is at least one of the causes of the strength of the mass. Another aspect to be considered is that all recent work on metals goes to show that boundaries between neighboring crystal grains in a mass of pure metal or homogeneous alloy are surfaces of strength. This may be attributed to the existence of surface tension in the boundaries, or to the presence of a layer of amorphous material, chemically identical with the crystals, between the surfaces of the latter. The reconversion of the hemihydrate into gypsum is accompanied by a decrease of volume. The apparent expansion is caused by the outward thrust of the lath-shaped crystals during their growth. Recent work goes to show that the difference between the supposed modifications of anhydrite are largely due to mere differences in the fineness of the particles. In experiments of Keane, gypsum which had been heated for some time at 600° was ground so that the average diameter of the particles was 0.05 mm. and then behaved as a dead-burnt plaster, being unable to set. The same product, ground until the average diameter was reduced to 0.005 mm., set rather rapidly, forming a hard mass. For the ceramic industry the principal requirement of a good plaster for moulds is porosity and strength. Many salts accelerate the setting, especially the soluble sulphates, while others, including borax, retard it. Generally, the accelerators are substances which increase the solubility of gypsum (or, more probably, of the hemihydrate), while retarders are substances which diminish the solubility. Assuming that the failure to make good plaster by re-burning old moulds is due to the absorption of soluble salts during use, thus completely altering the setting properties, it should be possible to wash out the salts from the coarsely broken material before submitting to re-burning. Such a washing process is applied in the manufacture of plaster from such gypsum deposits as those found in some parts of South Australia, containing a large pro-

portion of soluble salts. It would be necessary to grind the burnt plaster very finely before use. A. J. LAMBERT.

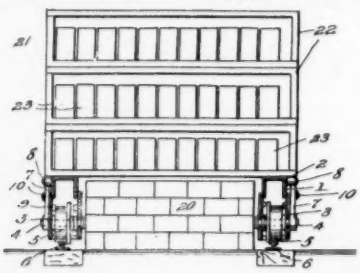
PATENTS

Cement, process of obtaining, and soluble potassium compounds. C. ELLIS. Reissue 14,773, Dec. 23, 1919. Original U. S. 1,186,522, June 6, 1916. G. E. MIDDLETON.

Brick and Tile

PATENTS

Brick-handling machinery. C. E. ROSS. U. S. 1,325,864, Dec. 23, 1919. After the bricks leave a cutting machine they are placed upon the pallet sections 21 of refractory clay, and these sections are mounted upon the truck in the manner shown, which sections are so formed that they may be arranged in superposed relation without bringing the bricks into contact with each other. In this loaded condition, the truck is pushed or otherwise conveyed to the kiln, and the assemblage of bricks and pallet sections are deposited upon the foundation 20 by lowering frame 2, so that the lower-most section rests directly upon the relatively broad upper face of said foundation. It



will be observed that owing to the width of the foundation, the pallet structure will be securely supported and all strain and stress entirely removed therefrom. The shorter vertically extended portions of each section form substantially solid vertical side walls, which materially increase the strength of the pallet structure and effectually prevent the latter from bending or warping when subjected to heat and weight. After the kiln has been thus filled, the bricks are burned and the truck again run into position beneath the assemblage of pallets and bricks and by operating the elevating mechanism of the truck, said assemblage is removed from engagement with the foundation and may be thus transported to any suitable position of removal.

G. E. MIDDLETON.

Chemical Stoneware

On the standardization of chemical stoneware. HARALD NIELSEN. *Trans. Ceram. Soc.*, **18,** 182–229 (1919).—The ultimate tensile strength of high class, English vitreous stoneware seems to vary between 600 and 800 lbs. per sq. inch, and material below this should not be used for chemical plant under

pressure. N. has found that a stoneware pipe calculated according to the simple formula: $w = \frac{p \times d}{2 \times u}$ where w = wall thickness in inches, p = pressure in pounds per sq. inch, d = diameter in inches, u = ultimate tensile strength in pounds per sq. inch, will stand the pressure required within the limits of u. The working safety margin should be reasonably large, and N. suggests 4 as the factor by which the w found by the formula should be multiplied. High pressure stoneware pipes of above 4 inches diameter should be avoided, partially because the wall thickness becomes rather heavy and drying difficult, and the chances of successful vitrification thus decreases. The most suitable flange-joint is the conical buttressed flange. In pipes for low pressure the wall should be made as thin as possible, and the limit should be strength necessary to stand carriage and handling. On no account should the glaze be relied upon to protect the actual stoneware from corrosion; unless the body itself is thoroughly vitrified, the glaze gives only a false sense of security. The strength of acid eggs or monte-jus can be calculated in precisely the same manner as the pressure piping, and the same formula can be used. The factor which governs the capacity of such vessels is the wall thickness required to resist the pressure. A vessel working under high pressure requires a very thick wall, and it becomes very difficult to produce such a vessel, as the wall will be difficult to dry and burn satisfactorily. Two and a quarter inches is about the limit for satisfactory working. A factor of safety for u of 2 is suggested. Instead of thin necks for inlet and outlets heavily bossed openings should be provided. Stoneware vessels should be as dense and vitreous in body as possible to avoid sweating. A preventive treatment is to fill the vessel before use with a strong sodium silicate solution for 24 hours; afterwards the vessel should be filled with acid, sulphuric or nitric, not too weak, for some few hours. Silicic acid separates out and fills the fine pores. A storage jar of $1\frac{1}{2}$ tons capacity was turned out, complete, in plaster of Paris molds, in 20 minutes by means of a huge jigger. Two operators, one standing on each side of the machine, threw lumps of clay as fast as they could into the mold. The lumps were quickly smoothed and kneaded into the exact form by the scraper. In screw presses for pipes up to 8 inches in diameter, the die should be arranged horizontally so that the pipe is shot vertically upwards between guides. In this way fine surface cracks can be avoided, which are formed when the pipes are shot out horizontally on a table. In discussing this paper M. Barret stated that the suitability of the salt glaze for the chemical stoneware has been much over-rated and the popular opinion that this type of glaze is the "ideal" is untrue. Such glazes are frequently too alkaline and are almost invariably covered with a fine network of crazes. Better results are obtained by using a felspathic glaze of the porcelain type, the composition of which is under control and which can be modified to suit varying conditions.

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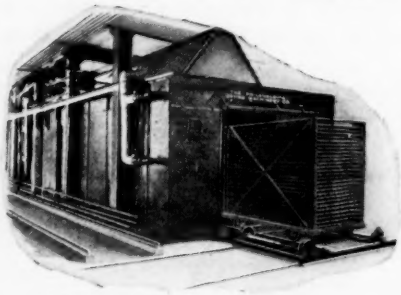

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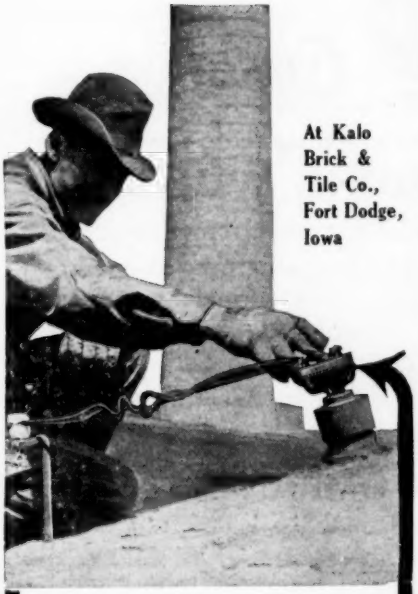

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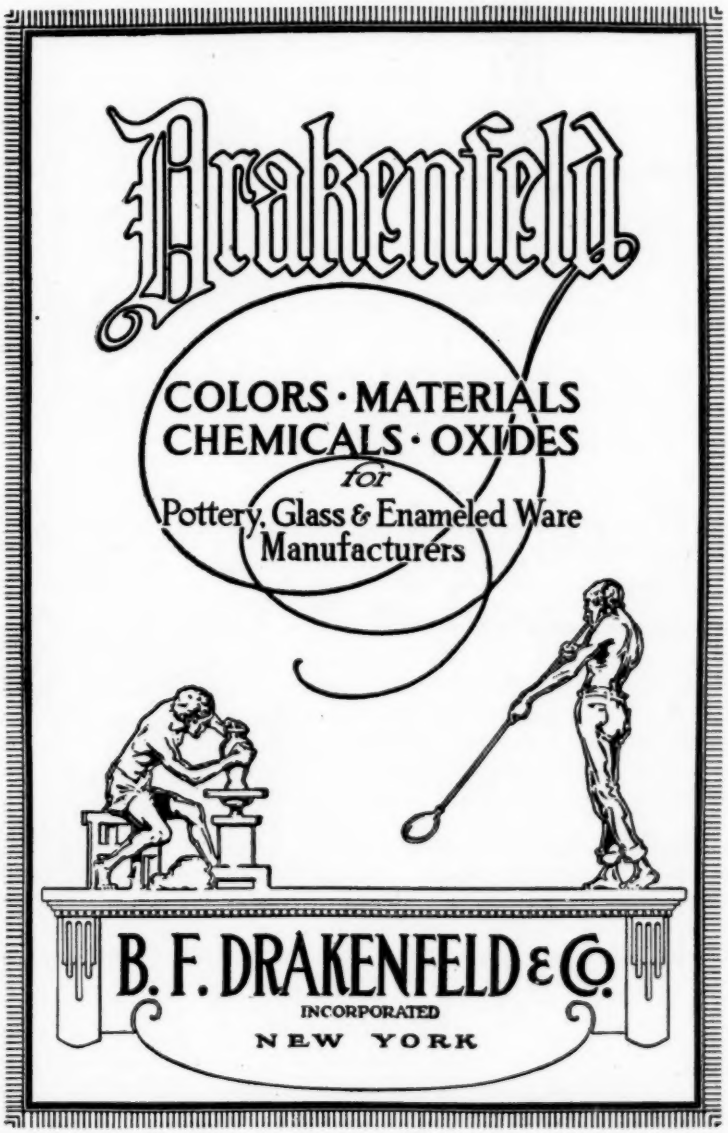
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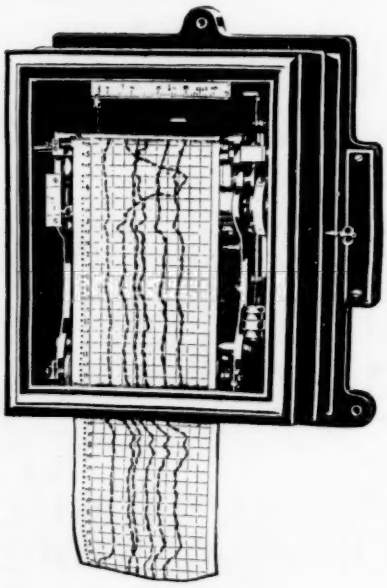

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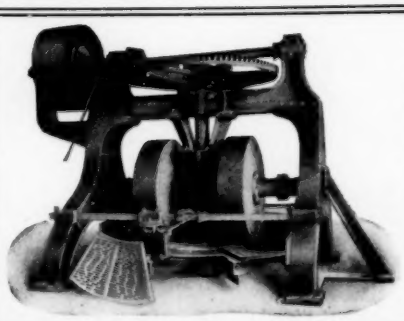

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